THE INFLUENCE OF BENCH HEIGHT AND EQUIPMENT SELECTION ON EFFECTIVE MINERAL RESOURCE UTILIZATION

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ABSTRACT

THE INFLUENCE OF BENCH HEIGHT AND EQUIPMENT SELECTION ON EFFECTIVE MINERAL RESOURCE UTILIZATION

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The mine planning process converts resources into economically mineable reserves, focusing on value addition and risk reduction. Equipment selection is traditionally addressed late in the process and addresses production capacity, equipment matching and equipment allocation. The primary focus being to reduce the operating cost per unit of material handled.

Mineral resource management is an integration of the key functions in the mining process. A focus on resource utilisation plays a key role in the management process and leads to the question whether lower operating costs always add value in the long term. It was determined that traditional equipment selection methods are not effective for all mineral deposits and might even be short sighted, destroying value over the long term.

The mine planning process was adapted to allow for an early investigation into the potential for increased recovery. The effect of selectivity in the loading action is simulated in a 3D environment over a range of bench heights. The results are analysed with a grade tonnage curve and the saleable product at each bench height is calculated, taking account of the required product qualities. The concept of financial materiality is applied to classify the resource as either a massive or selective deposit.

A massive deposit support the traditional drive for bigger equipment and will benefit from lower operating costs. A selective deposit requires less focus on production capacity, equipment matching and allocation and more on resource recovery.

In order to take advantage of the potential indicated in the evaluation, it is necessary to modify the traditional equipment selection techniques. A thorough understanding of the capabilities of the loading equipment is required in an attempt to match these abilities with the geometry of the ore deposit. The objective is to identify the equipment that will ensure the highest mining recovery at the lowest cost. This will be achieved when the loading equipment can attain a mining recovery smaller than the bench height it is mining or if the equipment can be applied economically on small bench heights.

The most suitable equipment can only be determined at the hand of a total value chain costing analyses. This means that the production cost i.e. the cost to produce the final product must be evaluated and not the operating cost i.e. the cost to move a unit of material, as is often the case.

The proposed mine planning approach and equipment selection technique was used on the Thabazimbi iron ore mine deposits. The results indicated that the NPV of the project could be increased dramatically. It was concluded that the ability to load selectively cannot be calculated mathematically. It is a judgment made on a thorough evaluation of the design and operating features of the shovel in conjunction with the ore body geometric parameters and the loading face conditions. The efficiency of the selected shovel can be manipulated through the application of different bench heights, and the optimum combination can only be determined through a total value chain costing analyses.

SAMEVATTING

DIE INVLOED VAN BANKHOOGTE EN TOERUSTING SELEKSIE OP EFFEKTIEWE BRON BENUTTING

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Die mynbou beplanningsproses omskep bronne in ekonomies mynbare reserwes, met die fokus op die toevoeging van waarde en die vermindering van risiko. Toerusting seleksie word tradisioneel laat in die proses aangespreek en fokus op produksie tempo’s , toerusting passing en die allokering van toerusting. Die primere fokus is die vermindering van die bedryfskoste per eenheid hanteer.

Mineraal bron bestuur is die integrasie van die kern funksies in die mynbou proses. ‘n Fokus op bron benutting speel ‘n kern rol in die bestuursproses en laat die vraag ontstaan of laer bedryfskostes altyd waarde toevoeg op die lang termyn. Daar is bepaal dat tradisionele toerusting seleksie metodes nie effektief is vir alle ertsliggame nie en mag self kortsigtig wees. Sodoende word waarde vernietig oor die lang termyn.

Die mynbou beplannings proses is aangepas om voorsiening te maak vir die vroeë identifisering van potensiaal om mynbou herwinning te verhoog. Die effek van selektiwiteit in die laai aksie is gesimuleer in 3D omgewing oor ‘n verskeidenheid bankhoogtes. Die resultate word deur middel van ‘n graad-tonnemaat kurwe ontleed die die verkoopbare produk is vir elke bankhoogte bereken met inagneming van die graad kwaliteite. Die konsep van finansïele bewesenheid word toegepas om die reserwe as ‘n massiewe of selektiewe afsetting te klassifiseer. ‘n Massiewe afsetting

ondersteun die tradisionele dryf na groter toerusting en sal die meeste voordeel trek uit goedkoper bedryfskoste. ‘n Selektiewe afsetting verlang minder fokus op produktiwiteit, toerusting passing en die allokering van toerusting.en meer op die selektiewe vermoë van die toerusting.

Om die voordeel te trek uit die potensiaal wat in die evaluering bepaal is, is dit nodig om die tradisionele toerusting seleksie tegnieke aan te pas. ‘n Deeglike begrip van die vermoë van die toerusting word benodig in ‘n poging om die vermoë met die geometrie van die ertsliggaam te pas. Die doel is om die toerusting te indetifiseer wat die beste mynbou herwinning teen die laagste koste sal verseker. Dit is moontlik wanneer die toerusting mynbou herwinning kan behaal wat kleiner is as die bankhoogte wat gemyn word, of as die toerusting ekonomies op lae bankhoogtes aangewend kan word.

Die keuse van die mees ekonomiese toerusting kan slegs gedoen word deur ‘n totale waardeketting koste evaluering toe te pas. Dit beteken dat die produksie koste, die koste om die finale produk te produseer, gemeet moet word en nie die operationele koste, die koste om ‘n eenheid materiaal te skuif nie, soos wat baie keer die geval is.

Die voorgestelde mynbou beplannings metode en toerusting seleksie tegniek is toegepas op die Thabazimbi ertsliggaam. Die resultate het aangedui dat die netto huidige waarde dramaties verhoog kan word. Daar is bepaal dat die vermoë van die toerusting nie wiskundig bereken kan word nie. Dit is ‘n oordeel wat gemaak word na ‘n volledige evaluering van die ontwerp en bedryfs eienskappe van die toerusting met inagneming van die geometrie van die liggaam en die laai front konsises Die effektiwiteit van die gekose laai toerusting kan gemanipuleer word deur die toepassing van verskillende bankhoogtes en die optimum keuse kan slegs gemaak word deur ‘n totale waardeketting koste evaluering.

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1 INTRODUCTION

1.1. Introduction and Background

Waste stripping contributes a significant percentage to the total production cost at a surface mining operation. It is important to utilize the best technology available to reduce this cost component to an absolute minimum. This can be done either by reducing the unit cost through the utilisation of bigger equipment and incorporating the equipment dimensions into the pit geometry or by a reduction in the required activity through a decreased stripping ratio. The stripping ratio can be defined as the units of waste that have to be removed in order to recover one unit of ore and can be measured in either tonnage or volume. This study will refer to a tonnage ratio. A decrease in the stripping ratio can be achieved in various ways. Steeper slope angles will make a significant difference in the stripping ratio. The utilisation of smaller equipment will also decrease the stripping ratio either by better ore recovery or by applying the design parameters applicable to such equipment such as narrower road widths and steeper haul road gradients.

Numerous references will indicate that “Bigger is better” and this philosophy is applied almost throughout the mining industry. While surface operations mining a massive ore body at a relative low stripping ratio might not encounter recovery and contamination problems of a magnitude that warrants material concern, it is often the smaller ore bodies that do. It is the conflicting nature of an attempt to reduce unit costs while maximising recovery that necessitates an investigation.

The influence of dilution and recovery is twofold. A decrease in recovery means that identified ore is treated as waste and does not generate income. The stripping ratio is effectively increased, reducing total revenue. The only way to prevent ore loss within the limitations of incorrect equipment application is to accept more dilution. This means including waste in the run of mine in an attempt to make sure that no ore is lost. This contributes to unnecessary transport and beneficiation costs.

The impact of increased dilution on the total production cost and thus profit is site specific. The impact can be significant where long transport distances are encountered. The degree of dilution accepted in a feasibility study will dictate the required process plant specifications, with an immense influence on the projected capital and operational expenditure.

Ore bodies can be classified as either massive or selective. Massive ore bodies imply that the dimensions and geometry of the ore body are of such nature that the affected part of the ore body is not large enough to have a material influence on the economic feasibility of the project. This means that bench height and equipment selection does not have a material influence on mining loss and contamination. This is usually associated with a homogenous ore body with a dip angle and dimensions that does not cause excessive dilution during loading. Low-grade intrusions usually do not occur, which simplifies the evaluation process. Selective ore bodies on the other hand imply that the affected part of the ore body is of such a dimension that it has a detrimental influence on the outcome of the economic feasibility. These ore bodies might be characterized by a narrow or lensic deposit, dipping at an angle and usually implies a higher stripping ratio. Improved recovery on a selective ore body can be obtained by utilizing smaller equipment, making the most of the mobility and ability to dig selectively. More flexibility in terms of grade control can be achieved with more production units producing from different areas simultaneously. Smaller haul trucks can contribute to a reduction in the stripping ratio in the instance where final pit slopes are influenced by access roads. Steeper, narrower haul roads, smaller turn radii on the access roads and smaller bench widths all contribute steeper slope angles.

Equipment suppliers on the other hand are investing significant capital and research funds in order to increase the equipment size to deliver a higher production rate at a lower unit cost in order to maximise return on investment. While bigger might equal better in terms of production rates and production costs, it certainly does not contribute to a higher recovery and lower dilution in order to optimize the utilization of a selective resource.

While substantial literature exists on the selection of equipment for surface mining operations, the need for a total value chain evaluation in terms of production cost (dictated by equipment selection and bench height) versus resource utilization has been identified. Such research should not only address the selection of an appropriate shovel and bench height but also should consider the consequent total production cost and return on investment, which is likely to be dictated by the ore recovery.

1.2. Problem Definition

While surface operations mining a massive ore body at a relative low stripping ratio might not encounter recovery and contamination problems of a magnitude that warrants concern, it is often the smaller ore bodies that do. These ore bodies, being thin and dipping at an angle are often mined at a higher stripping ratio. High production rates are pursued in an attempt to reduce unit costs in order to counter the high production cost. This implies selecting high capacity mining equipment and increasing bench height in order to produce at lower unit costs. (Çebi, Köse, Yalçin. 1994). The consequent equipment selection and pit geometry is likely to reduce ore recovery, increasing the final stripping ratio and thus final product costs. This tendency is increased where precious minerals or commodities of high value are mined.

> Matching equipment selection and pit geometry to achieve maximum resource utilization at the lowest cost per saleable ton of product, is the challenge to the mining engineer.

In order to address this problem, the following sub problems will be investigated:

1.2.1 What is the current practice in equipment selection methods? Is the full potential of selective mining considered? What does the current world shovel population indicate?

1.2.2 What is the correlation between the geometry of the ore body, the bench height and the ore recovery and dilution? Can the ore bodies be categorised in terms of these parameters to determine the maximum economic bench height?

1.2.3 What is the influence of shovel selection on the recovery and dilution at any specific bench height? Can the efficiency of a shovel selection be increased in terms of recovery and dilution through the manipulation of the bench height?

1.2.4 The total equipment fleet and bench height will ultimately determine the production cost per unit handled and, taking into account the consequent recovery and contamination, the cost per unit sold. A costing evaluation over the whole value chain is required, considering all the relevant performance indicators, to indicate which combination of parameters will yield the highest return on investment.

1.3. Objectives of the Study

The study will develop a systematic model that can be used in the evaluation of a wide range of reserves in the initial planning phase to determine the most economic pit geometry and equipment selection. Attention will be given to the combination of bench height and equipment selection to maximise the return on investor's capital through efficient resource utilization at the lowest unit cost. It is the objective of the study to sensitize the industry to the economic implications of applying a total value chain evaluation approach in equipment selection compared to a decision criterion based on the lowest cost per unit handled. The impact of less than optimum recovery and dilution can more than outweigh the advantages gained by applying the principles of economies of scale in equipment selection and pit design. This impact is however dictated by the geometry of the ore body, ore qualities, ore-waste contacts and type of beneficiation.

These objectives will be met in part through a review of mine planning and the role it plays in pre-determining equipment selection, a review of the equipment selection process itself and through application and evaluation of the proposed technique to an operating mine.

In developing a solution to the primary objective, the following intermediate objectives will be addressed:

1.3.1 Ore deposit classification

The ore deposit must be classified as either a massive or selective deposit. This is done through the application of a 3 dimensional simulation of the loading action on various bench heights. The economic impact is evaluated in terms of financial materiality and a judgment is made based on the results. The purpose of the classification is to determine whether the focus of the equipment selection process should be on high volume, low cost applications or on specialised selective mining equipment.

1.3.2 Shovel evaluation

A thorough understanding of the unique features of each shovel type will be required in order to determine the effective application range in terms of bench height. It is the objective of the study to critically review the various shovel features that will impact on selective loading ability.

1.3.3 Equipment selection.

The optimum shovel selection can only be achieved if the characteristics of the ore body and the unique ability of the shovel are matched. This process will be illustrated through the application of the proposed technique to determine the optimum shovel type and bench height combination for an operating mine.

1.3.4 Total value chain cost evaluation.

A systematic, iterative approach will be applied to evaluate each scenario. The economic evaluation will be done over the total value chain, taking into account the relevant mining recovery and production cost for each scenario, and evaluating the net present value (NPV).

1.4. Scope and Structure of the Study

1.4.1 Scope of study

This study is intended to evaluate the economic consequences of matching the optimum bench height with the unique features of the loading equipment. Special reference will be made to the impact of resource utilization on the net present value of a project. It is not the intent of the author to determine the economic feasibility of a project but rather to do a comparative analysis for different scenarios.

The selection of specific production drills will not be considered here, but the ensuing production cost and optimum blast design will be incorporated in the value chain costing evaluation.

The influence of the size of equipment selection on a pit layout and stripping ratio will be discussed briefly. Although it is not the intent of the author to evaluate the total impact on the final pit layout, the magnitude of the impact is of such proportions that it cannot be entirely ignored.

Although the study will be developed from the specific case of iron ore operations, a generic approach will be suggested which can be applied to any selective resource in the early planning phases.

Only the most applicable shovel types will be evaluated, e.g. rope shovels, hydraulic excavators in a backhoe and shovel configuration and wheel loaders. The use of specific brand names does not indicate a preference for those makes of equipment, only that specifications of those specific machines where used to represent the class of equipment.

1.4.2 Structure of the study

The current state of equipment selection techniques is evaluated and discussed in Chapter 2. Actual studies by the end user are considered in combination with the suppliers' viewpoints on selective mining. Inherent deficiencies in terms of resource utilisation are highlighted, from the perspective of inappropriate loading equipment selection.

In Chapter 3 the importance of resource utilization is highlighted in terms of total resource management. The implications of the South African code for reporting of mineral resources and mineral reserves (*SAMREC code, 2000*) on required knowledge in terms of ore recovery and dilution are highlighted. The implications of selectivity on the evaluation of iron ore deposits are discussed, leading to a detail evaluation of the Thabazimbi iron ore deposit. Finally the Thabazimbi deposit is evaluated with a 3 dimensional simulation to determine the potential for increased recovery and the results are interpreted in terms of financial materiality.

Chapter 4 initially reviews the current world trend in terms of shovel population to ascertain end-user driven development issues. The different shovel types are discussed in terms of the design and operating characteristics in an attempt to better understand the unique abilities of each shovel. These abilities are evaluated in terms of the selective loading capability of each shovel at different bench heights. An equipment selection process for a selective ore body, which incorporates the bench height, production efficiency, selective loading ability, operating cost and mining recovery is proposed which will be used in the economic evaluation in chapter 5.

In Chapter 5 an economic evaluation is carried out for various equipment selection and bench height geometry scenarios. The evaluation incorporates the total mining process and the results are used to determine the optimum combination of ore body geometry and equipment capability. In Chapter 6 various alternatives are discussed from a practical implementation perspective, which can either increase the advantage gained through focused equipment selection, or to generalise these principles to any given set of circumstances. Chapter 7 provides the conclusions and recommendations for further research.

2 CURRENT STATE OF EQUIPMENT SELECTION CONSIDERATIONS

2.1. Introduction

The current state of equipment selection techniques and considerations are reviewed and discussed in terms of available literature on this subject. The mine planning process is analysed to determine the impact of equipment selection. Initially, equipment selection techniques are classified according to the various methods determined from the literature and the results of previous studies are evaluated. These techniques are then critically reviewed in the light of the problem statement. A summary is made of the equipment selection factors to consider according to various authors, with special reference to the influence of bench height. Finally the manufacturers viewpoints are considered together with the general viewpoints of the author before development opportunities are identified and recommendations are made for further research.

In order to evaluate the equipment selection techniques it is necessary to know where this procedure fits into the planning cycle.

2.2. The Mine Planning Process

The mine planning process is the engineering process that converts resources into economically mineable reserves. The purpose of the planning process should be to add value to the resource base through a series of processes, taking into account a number of interrelated elements or modifying factors. These factors include the market, metallurgical process, mining method, corporate objectives as well as legal, environmental and political constraints. The most important characteristic of the mine planning process, arising from the interrelated nature of the above-mentioned elements, is that it is an iterative process with potential improvement from each iteration. The planning process as depicted in figure 2.1 is a generic representation applicable to most mining operations. This resource to reserve engineering is the core function of the mineral resource management process. It should be conducted according to a mapped out or sequential process and according to set protocols and standards. Each specialist must be aware of exactly what outputs are required to proceed to the next phase.

Each element will be discussed in more detail in the following sections.

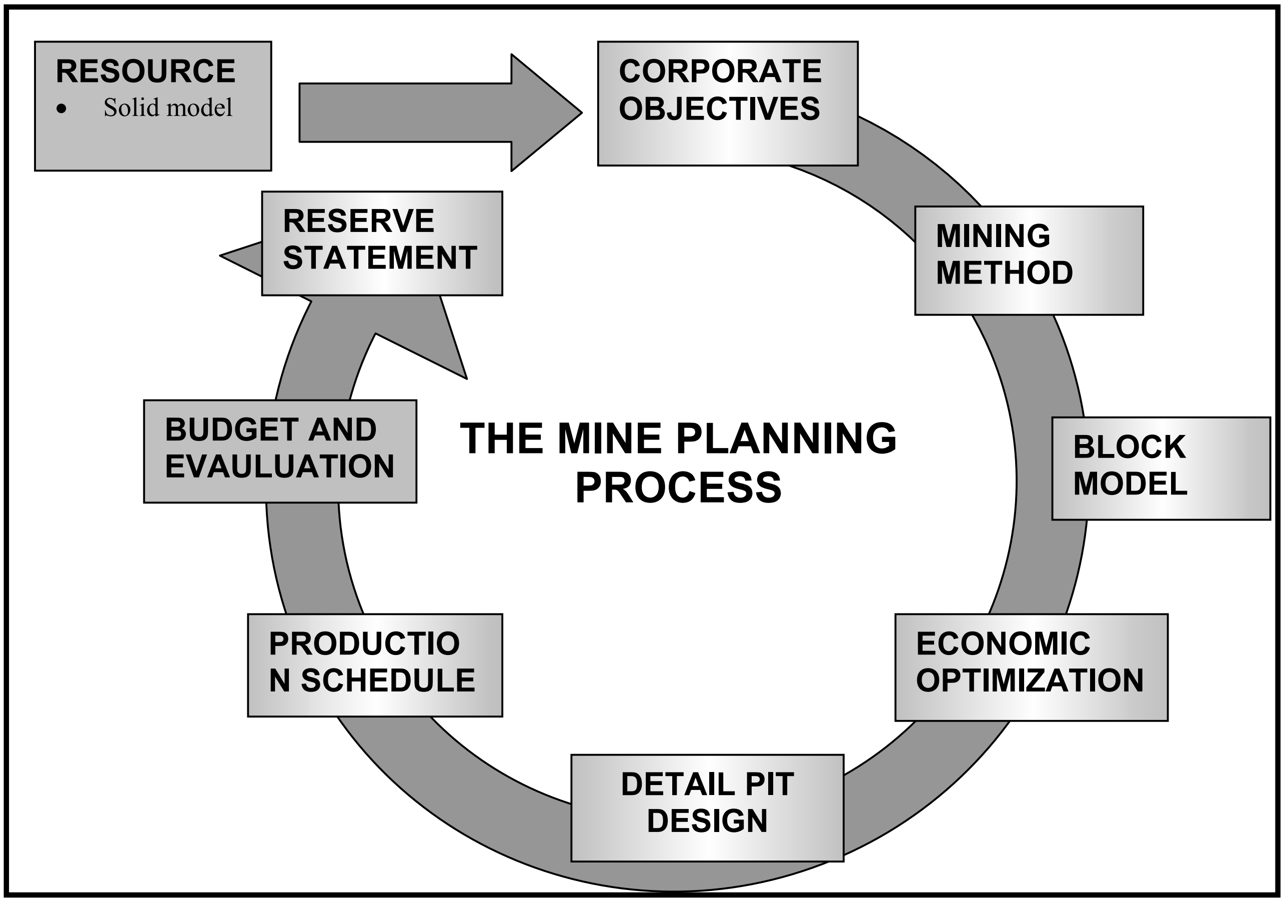


Figure 2.1 Generic representation of the mine planning process

2.2.1 The Resource

The process of resource estimation consists of 4 main activities, which are geo-scientific data collection, model derivation and validation, resource estimation and classification. The output should comprise a 3D solid model, which explains the grade distribution pattern and the volume available for possible economic extraction. The SAMREC code is prescriptive regarding minimum standards for resource classification. If need be, a distinction can be made between global, published and planning resources. The shape and structure of the ore body and waste rock should be assessed and used to select mining methods. The challenge of the mining engineer is to convert as much as possible of the available resource into economic reserves using innovative design techniques.

2.2.2 Corporate objectives

Pit optimization produces results based on the maximum NPV. The NPV is the net present value of future cash flows discounted at a selected discount rate. Companies may have other or additional corporate objectives. These objectives may include life of mine, maximum cost of production, scale of operations, ability to adjust to external factors, exposure to risk or utilization of the resource. The cost associated to these objectives has to be quantified. These objectives have to be understood and agreed upon in order to optimize the plan within the set framework.

2.2.3 The Mining Method

Once the resource has been established and the corporate boundaries have been fixed, the decision must be made on how the ore body should be mined. Various factors must be considered such as the nature of the ore body and the associated waste rock, the scale of operations, the need for selective mining, acceptable levels of dilution and ore loss and the unit value of the ore in the ground (Crone 1992). But it is too early to determine any of these factors accurately which means that assumptions have to be made. This implies that the selection of the mining method is the first step in the iterative process of mine planning. Usually the decision can be made on whether underground or surface mining methods would be the most economic, and this is a good starting point.

2.2.4 Construct a Block Model

The block model is constructed from the solid model and serves as the input to the pit optimization. There are four block sizes which are relevant, namely; for outlining the ore body, for calculating the block values, for designing the pit and for sensitivity analyses (Whittle 1989). The block value should be calculated on a block size, which is determined by the equipment type as well as the spacing of the data points. A minimum limit determined by the equipment type should be such that it can be mined separately. If this is not done an inaccurate estimation of the mineable reserve may be calculated. This means that the equipment selection should already have received sufficient attention at this early stage.

2.2.5 Economic optimization

The first thing to realize is that any pit outline has a monetary value, which can be calculated. Pit optimization is the process of determining the optimal outline or shell to be mined to realize the maximum profit. This is achieved by assigning a value to each and every block generated in the block model and calculating the combination of blocks that will achieve the highest value. The calculation is very sensitive to production costs, pit slopes and income generated. It is clear that the size of the blocks that are mined and generates income should correlate with the selective ability of the equipment. The bench geometry and production costs should also be reflecting the equipment selected. It is again obvious that equipment selection should receive thorough investigation at this early stage.

2.2.6 Detail Pit design

The purpose of the detail pit design is to transform the economic pit shell into a practical mineable layout. The aim is to produce a design that deviates as little as possible from the outline of the optimization. Factors to be considered are the detail geological boundaries, access to the open-pit, waste dump design, topography, existing infrastructure, design slopes and pit design parameters which are road widths, gradient and maximum road curvature, bench interval and bench height, sequence of extraction and even blasting techniques which will effect the ultimate pit slopes. It is again obvious that equipment selection has a significant influence on the detailed open pit design.

2.2.7 Production schedule

With an ultimate pit defined, open pit planning and scheduling consists of deciding how to proceed from the unmined ore body to the ultimate pit. The technique depends on the critical drivers. It can be driven by maximum NPV or the achievement of a constant quality of output may be more important. Whichever technique is adopted, open pit planning and scheduling is a design problem. Just as it is necessary to revise and rework a design to arrive at the optimum result, so open pit scheduling benefits from applying an iterative approach. In this stage the production rates of the equipment is the critical input. Traditionally this is the area where a significant emphasis is placed on equipment selection and especially equipment matching. It is now important to be able to simulate the expected selectivity because this can and will have a profound influence on the waste stripping rate when scheduling towards a pre-set target. When the design and schedule has been completed the viability of the project can be projected.

2.2.8 Project budget and evaluation

At this stage all the information is available to do detail costing and financial analyses. Production budgets can be compiled and equipment maintenance planning can be done. This is also the stage where the benefits of increased ore utilization can be determined at the expense of higher production costs.

2.2.9 Reserve Base

According to the SAMREC code the definition of a Reserve is ***"the economically mineable material derived from a Measured and/or Indicated Mineral Resource "***. Once this stage has been reached it is possible to report the economic reserve which has been established from the given resource base which can vary significantly when various combinations of equipment are matched to selective ore bodies.

2.3. Classification of equipment selection techniques

The traditional approach to computerized open-pit design requires defining ultimate pit limits prior to completing detailed final equipment selection. This is done by making assumptions concerning economic conditions, specifically waste rock and ore mining costs, excavation geometry, pit slopes, selectivity, bench height, production rates, excavation sequence etc. In the design process the block size should be related to the size of the selective mining units (SMU) which is the smallest size on which it is possible to make a mining decision. (Lizotte 1988*). A*ll of these input parameters are affected by the equipment selection. Runge (1988) points out that the cost of mining must initially assume certain size blocks and equipment types, even though block sizes and equipment types cannot be determined until after the reserves are known. The decision criteria concerning equipment selection and pit design conflict, indicating the necessity for iterative design procedures, or “circular analysis”.

To ensure the successful operation of a mine, the most appropriate method of determining the most economic mine size and equipment configuration has to be applied. The development of the hydraulic excavator/shovel and the wheel loader over the last decade ensures that there exists considerable flexibility in the selection of mining equipment. New technology, coupled with the inherent economies of scale, justifies the move towards larger equipment on a cost per ton basis. Over the last few years numerous studies have proved that the best economies of scale from a cost per ton basis are achieved when employing the largest possible haul trucks with a large electric mining shovel, minimizing the number of passes. (Sullivan 1990*)* This phenomenon should be challenged under certain conditions. While this might be true from the limited perspective of cost per ton mined, it is possible that expected savings would not realize because of high ore losses. When considering the larger picture of resource utilization, a substantial increase in revenue can be generated through better ore recovery, but at a higher production cost. Today the equipment selection process warrants increasing accuracy due to the considerable capital outlays associated with large-scale surface operations and the considerable cost saving that can be achieved by proper equipment selection. With the inclusion of low-grade ore and narrower cost-revenue margins, closer inspection of mining parameters has to be made.

According to Ercelebi and Kirmanli (2000), surface mining equipment selection techniques can be classified as Classical, Operations Research or Artificial intelligence methods. Operations research techniques include Linear-Integer programming, Simulation and Queuing theory. Artificial intelligent methods have become very popular recently and include Expert System-Knowledge Based Decision System and Generic Algorithms that have been applied frequently. These latter methods however, require a clear understanding of the underlying knowledge-base and solution- selection and -chaining criteria applied to the initial problem. It is an attempt to formalise the hitherto fragmented approach to equipment selection but tends nevertheless to be application specific and subjective.

The proposed Value Chain Costing analyses to determine the optimum equipment selection does not intend to replace any of the existing equipment selection techniques. Replacing may however occur depending on the output required from any technique. The overlap might be of such nature that the application of another technique is not necessary. The focus of the proposed analyses is the application of the loading equipment and the interaction of the equipment with the geological and bench geometry. The successful application of this analysis will determine the optimum bench geometry and shovel type and will thus impose limits on the equipment selection to be used in any of the established selection techniques.

2.3.1 Classical equipment selection techniques

The objective of the Classical methods is to select equipment subject to production constraints. A familiar example is the selection of a shovel size and then assigning matched trucks to the shovel. The main assumption behind this approach is such that the excavating or loading and transport operations are interdependent and the optimum cost per ton may not be obtained by attempting to minimize each of the individual costs. This is a valid assumption and supports the viewpoint that the optimum cost per ton does not necessarily start at the lowest loading or excavating cost. Due to the high capital outlays required when purchasing equipment, the mine size and subsequent life of mine must be considered when production costs are calculated. Inadequate time for depreciation might contribute to high production costs.

This technique is applied by Rumfelt (1961) in one of the earliest studies, who developed deterministic equations based on pit design and equipment characteristics for draglines and shovels. He developed the maximum usefulness factor (MUF) which relates the weight of the equipment to its ability to do work. Morgan (1975) developed the concept of 'Match factor' for sizing loading and hauling equipment. Atkinson (1992) provided mine selection and sizing of excavating equipment in a surface mine.

2.3.2 Operations research-based equipment selection techniques

The application of Linear-Integer Programming to surface mining equipment selection mainly deals with equipment allocation to loading points. The issues addressed are the selection of shovel locations, how trucks ought to be assigned to shovels in order to be sufficient and how many trucks to be assigned to a shovel in order to achieve the desired production objectives. The objective of the model is to select that mix of equipment that represents the lowest cost schedule and still conforms to the constraints presented by the production goal and the mining conditions and practices. This technique however does not address shovel selection in terms of any parameter other than production rate. These solutions tend to be highly application-specific and, although technically correct, do little to further a generic approach to equipment selection based on geometric constraints. It would be more applicable once the type of shovel has been determined to assist in applying the Match Factor as developed by Morgan (1975). Lambert & Mutmansky (1973) developed a general model and another typical example is by Li (1989).

Simulation is a process through which a model can be built to represent a proposed or real equipment configuration and then used to gain insight into the performance of various equipment combinations in a production fleet. It is currently commonly applied to determine required fleet size, realistic production rate, equipment utilisation and production costs. The simulation does not look at the interaction between the shovel and the material being loaded but rather at the interaction between the shovel and the haul truck fleet.

The queuing theory deals with assigning trucks to shovels. Models estimate cycle times and indicates waiting times at the different service points and determines equipment utilisation. The results can be used to select proper shovel and truck combinations and determine the optimum fleet size. This is again a matter of matching equipment to achieve the best overall production rate and equipment utilisation and does not address shovel application in terms of the ore body geometry.

2.3.3 Artificial Intelligence

An expert system or Intelligent Knowledge Based System (IKBS) is a computer program that uses knowledge (either subjective or objective) and inference procedures to solve problems. Most IKBS's use a rule based approach, usually in the form of:

IF [(antecedent1) (antecedent2)]
THEN [(consequence1) (consequence2)]

Lizotte (1988*)* states that the process of equipment selection involves computations, executed in a logical sequence prescribed by the experienced equipment selection engineer. This is best corroborated by the fact that numerous attempts have already been made to develop expert systems applied to equipment selection.

Figure 2.2 shows a hydraulic excavator and truck selection knowledge base path used by Clarke et al (1990). The objective of this part of the software is to select an optimum hydraulic excavator and compatible truck configuration. The geology knowledge base contains all the rock information that governs hydraulic excavator selection. According to Ercelebi and Kirmanli (2000*)* the major factor to be considered is the required production. This system does show the most potential and could be developed to take ore body geometry and ore recovery into account through a knowledge base in order to do a shovel selection that maximizes recovery, minimizes dilution and performs optimally under specified bench geometries. This additional knowledge input is illustrated in figure 2.2.

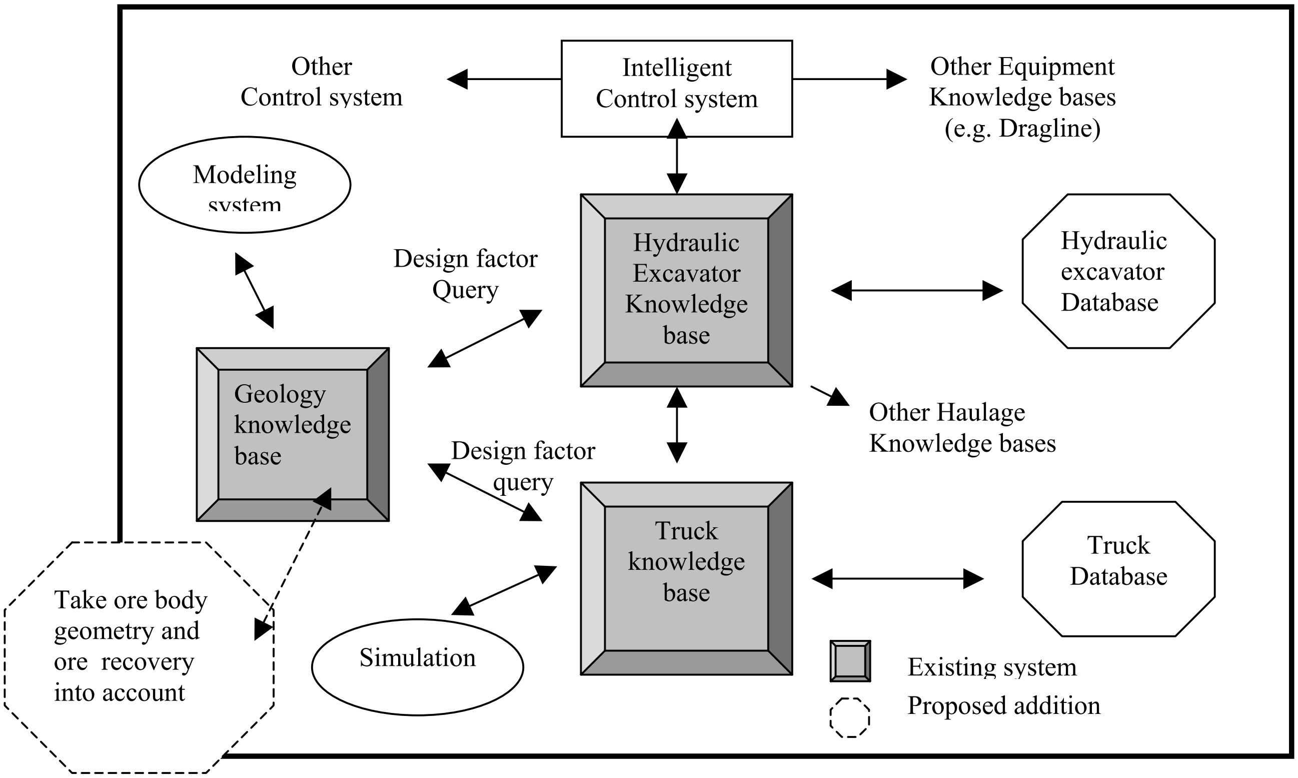


Figure 2.2 Hydraulic excavator and truck selection knowledge base, modified (Clarke et al 1990)

2.4. Previous equipment selection studies

Runge (1988) discusses the prominent role that equipment selection plays in determining the optimum pit geometry. Very few mines today operate under conditions where similar equipment is used for both ore and waste mining. If after determining the optimum pit boundary, the viable reserves so established mean a mix of equipment or mining methods, then the analyses will have to be undertaken again, using different assumptions. He describes the iterative nature of equipment selection and pit optimisation by means of the following example:

If a mine is assumed to be limited in extent, mining of it may need to be undertaken with smaller, higher cost equipment to increase mining recovery. When the pit is optimised the Lerch-Grosmann technique (Lerch and Grosmann 1965*)* indeed indicates a smaller pit. If on the other hand costs assigned to the blocks were based on large scale low operating cost equipment, an optimised pit will be much bigger and reserves may then be enough to vindicate the initial judgment to cost it on the basis of the large-scale equipment.

According to Runge, when mining a selective ore body, it may require a change in waste removal techniques. When the increased cost of this technique is calculated against the unit of ore, it could render it uneconomic. Although it is true that the extent of selective mining can have a large impact on mining costs, it is however the intent of the study to indicate the circumstances in which a substantial increase in material handling costs can most likely be justified by the increased ore recovery and thus increased revenue.

Hendricks et al (1988) reports on a series of field studies on the influence of bench environment factors on shovel digging performance, using what would be called a classical approach. Hydraulic excavators and electric shovels were studied and the conclusion was made that shovel location within a blasted bench volume, together with muck pile height, were seen to govern dig cycle time and thus shovel productivity. Scoble and Muftuoglo (1984*)* reported on the monitoring of the instrumentation of a CAT 245 hydraulic shovel to determine stick, boom and bucket hydraulic pressures during the dig cycle. These were related to shovel digging performance in a range of coalmine bench environments. The control of bench height over dig cycle time was evident in this study. It is evident from this information that a decrease in bench height will lead to increased production costs, but in order to asses the economics of the decision, the effect of resource utilization has to taken into account.

Cebi (1994) identified the need for a computer-aided method of equipment selection and evaluation in order to speed up the total evaluation process. A computer program package was developed which consisted of various subroutines addressing drilling and blasting, shovel and truck selection, crusher and conveyor and auxiliary equipment selection. The shovel calculations were based on available working time, cycle time, bucket size and fill factor and the required volume. All the other equipment selection criteria were based on possible production rates. It is thus clear that although this program might assist in cost calculations and the determination of the required fleet size, it does not address the efficiency of a shovel selection under the specific geological and geometrical constraints imposed by a selective ore body.

In a study on the economic and technical relations between open pit design and equipment selection, Lizotte (1988*)* highlights specific features that are pertinent to the selection process.

After assessing the site specific conditions, the equipment selection process implies choosing the types of equipment, the size of equipment and the number of units required to meet a determined production rate. Proper matching of the equipment is also inherent to the process. This is a valid comment but lacks another dimension that is often not addressed in the selection process namely the interaction of the loading equipment and bench geometry.

Equipment is selected as a function of the deposit geometry and will affect the excavation geometry. This seems to be a comment that refers to general accepted practice but once the economic evaluation is done, and an indication of high production costs is evident, the process often returns to the first dimension of determining the size and number of units to meet the production target at the lowest cost.

Cost estimation is an intrinsic component of the complete process. In fact the essential objective is to select equipment which will minimize a specified measure of cost. The question to be answered is which measure of cost should be addressed. The total cost of a unit of saleable ore is contaminated by many other variables and the influence of the selected equipment is not easily detected. It is only by applying a total Value Chain Costing analyses that it becomes evident that equipment selection can and should be done in order to minimise the total cost of a saleable unit and not only the cost per unit handled be it either waste or ore.

A case study at the Telfer Gold Mine, Western Australia (Arnold and Whitham 1991*)* addresses very relevant issues relating bench height to recovery and dilution and eventually total production costs. It is noteworthy that bench height is determined by recovery and dilution and not equipment efficiency. The authors acknowledge that geological and ore reserve block models are constructed to reflect the character of the mineralisation while few tools are available to manipulate block model data in a way that emulates mining processes. This study will attempt to do exactly this in order to simulate the application of different shovel types to determine the efficiency in terms of recovery and dilution.

In the Telfer Mine study it was established that future mining equipment and methods should provide the following:

- Adequate selectivity
- Low unit cost to permit maximum recovery of low grade resources.
- High volume to ensure required gold production.

The reason for the last mentioned is because of the fact that the revenue is sensitive to the mill feed tonnage. This principle will apply to most mining operations. It is not difficult to realize that these requirements are in conflict with one another and highlights the need for a fresh approach to equipment selection.

The following important results were derived in the Telfer Mine Study:

- Bench height is the primary variable of interest as this has direct bearing on costs, recovery, dilution and the productivity and cost effectiveness of the different mining equipment options.
- The analysis indicated that maximising the mill feed rate would maximise the net revenue. Selective mining tends to inhibit ore accessibility, which will impact high throughput options.

The cost benefit for increased bench height is shown in relation to a basic cost at 3-meter bench height (Table 2.1). The reduction in revenue is related to the cost benefit. It was concluded from these results that the cost penalty of selective mining appears to be more than outweighed by the improved recovery associated with selective mining. The bench height also has an effect on the accuracy of the grade predictions in depth.

Table 2.1 Relative production costs (after Arnold and Whitham 1991)

Bench height	**3m**	**4m**	**5m**	**6m**	**8m**	**10m**
Cost	100%	93%	91%	88%	80%	73%
Revenue	100%	99%	95%	92%	90%	82%

2.5. Equipment selection; factors to consider

It is evident from current literature that the selection of equipment has become more complex due to the wide range of equipment available and the specialized applications that the equipment is intended for. The increased pressure on the profitability of mining operations has, on the one hand prompted the development of bigger equipment in order to lower production costs through the principle of economies of scale. On the other hand it has fueled the development of more specialized equipment because no operation can afford to utilize equipment that is not one hundred percent effective in its application area. By studying the recommendations of various authors, it is obvious that some generic performance areas have to be addressed. There are however criteria that are site specific and do not apply to all applications. Table 2.2 summarises the various selection factors considered by various authors.

Table 2.2 A summary of some Key Issues to consider when selecting equipment.

	Ercelebi & Kirmanli (2000)	**Crone (1992)**	**Hrebar (1997)**	**Singhal (1986)**	**Lizotte (1988)**	**Sullivan (1990)**	**Dahlstrand, Hendricks (1979)**
Life of mine	♦	♦	♦				♦
Bench height	♦		♦				
Floor condition	♦		♦		♦		
Haul distance and haul grade	♦			♦	♦		♦
Material characteristic	♦	♦	♦	♦	♦		♦
Required prod. rate	♦		♦	♦	♦		♦
Operating Cost	♦		♦	♦	♦		♦
Need for selective mining		♦		♦	♦	♦	
Recovery, Dilution		♦		♦			
Value of material		♦					
Pit room						♦	♦
Weather				♦	♦		♦
Processing plant requirements				♦			
Environmental				♦	♦		
Infrastructure and Energy requirements			♦			♦	

From the table it is clear that material characteristics, required production rate and operating cost be equally recognized as factors to consider when selecting equipment. Material characteristics can be singled out as the factor that is mentioned by most of the authors. Although selective mining is not new to the mining industry, the full impact of recovery and dilution has not been addressed throughout the whole planning process and is only addressed by Crone (1992) and Singhal (1986). Mine planning is an interrelated process taking into account various elements including the mineral deposit, mining method, open pit design, scale of operations and treatment process all of which are influenced by the selection and application of equipment (Crone 1992*).* It is important to note that these elements cover the whole spectrum of the mining process, which means that the selection of equipment must be addressed before the open pit design is finalized. This is in contrast to a suggestion by Westcott (1991) that less significance is placed on equipment optimization in the early planning stages but that it has a significant impact in the detail planning stage.

While selectivity is recognized as a factor to consider, it does impose a limit on the size of the shovel and probably on the size of the trucks as well. This implies a loss in opportunity to reduce costs through the economies of scale as indicated in Figure 2.3

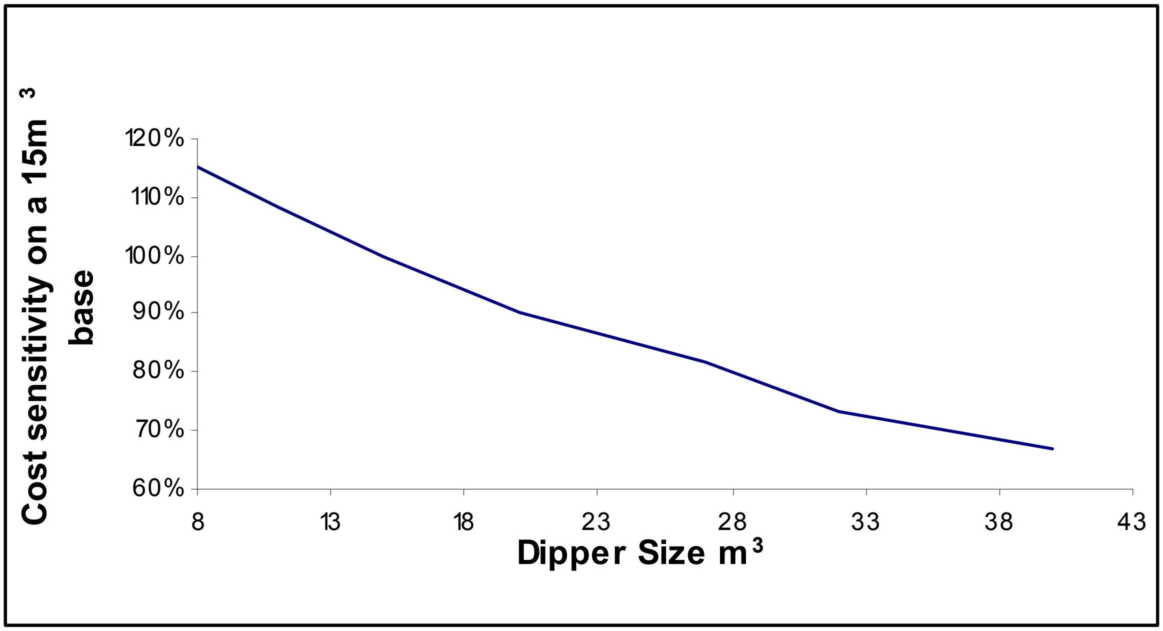


Figure 2.3 Cost sensitivity based on Shovel Dipper Size using a $15m^3$ base price (After Sullivan 1990)

The influence of haulage equipment selection goes far beyond the calculated production cost. Because access is required to the pit bottom, the narrower ramp width required by smaller trucks could affect the final slope (Hendricks, Dahlstrand (1979) and Anon (1979)). Pit slopes are undoubtedly one of the prime factors governing the feasibility of open pit mining. A slight modification on the pit slopes can result in a difference of millions of tons of waste removal. Thus by acknowledging the relationship between shovel size and truck size (matching theory) the influence of shovel selection on the pit slope and ultimately economy of the operations is evident.

Finally Singhal (1988) summarises the various factors involved in the equipment selection process. It is a very complete model taking into account almost every possible factor. Although the need for selectivity is discussed the full impact of resource utilisation is not considered economically. The set objective is cost per ton, but the question that remains to be answered is whether this is a ton moved or sold. The strategies supporting either one of these answers are worlds apart and will have a material influence on the economy of the operation.

2.5.1 Bench height

Bench height plays a vital role in the equipment selection process. It can be described as the interface of the selection process influencing both the equipment selection and recovery and dilution. It is not a factor that is a derivative of any decision but rather the initiator of the whole process. It is the key indicator that swings the decision either in favor of production costs or resource utilisation. It is a well-known fact that higher bench heights will normally result in lower operating cost (Lizotte 1988) but equally increases dilution during loading and blasting. A relationship between bench height and bucket size as used by Bilgin, Celebi, Pasamehmetoglu (1988) in a drill selection model is shown in Table 2.3. It indicates that the bucket size increase with an increase in bench height which, with reference to figure 2.3, allows for lower operating cost throughout the whole operating cycle.

Table 2.3 Relationship of bench height to bucket size

Bucket size m^3	**Bench Height (m)**
<5.0	9
5.1 – 8.0	12
8.1 – 20.0	14
20.1 – 30.0	16
> 30.0	18

In a study on electric mining shovel diggability (Hendricks 1988) it was concluded that the control of bench height over dig cycle time was evident. Domaschenz (2001) also indicates that the bench height has a large influence on the efficiency of the excavator performance. In an attempt to optimize mining selectivity in Telfer Gold Mine (Arnold and Whitham 1991*)* it was concluded that bench height is the primary variable of interest, as this has a bearing on costs, recovery, dilution, productivity and cost effectiveness of the different mining equipment options. The influence of bench height on the mining cost as determined during the Telfer study was shown in table 2.1. It is evident that the costs increase dramatically with a decrease in bench height.

Dahlstrand (1979) discusses the interaction between bench height and equipment selection. Bench height might determine the type and size of equipment or visa versa. Two different approaches are proposed in determining the bench height:

- Vertical distribution of ore. In the case where an ore body is irregular, both vertically and horizontally, there could be various bench heights that would optimize the ore recovery or minimize dilution.
- Required production rates: The planned production requirements will determine the size and/or quantity of equipment used in the mine. The desired bench height will be determined within certain limits by the size and type of equipment. In general, savings can be realized if the bench

height can be made equal to the maximum vertical working height of the loading and drilling equipment.

It is again evident that these considerations oppose each other and that a detailed Value Chain Costing analyses will be required to determine the optimum combination of selectivity and operational cost over the life of the project.

Since bench height plays a pivotal role in the efficient utilization of the resource it should be incorporated during the open pit design. Dahlstrand suggests that a computer model (3D grid model) should be used to simulate the mining at varied bench heights in order to determine the height for optimum reserve utilisation. The block dimensions used in computerised pit design assume selectivity of a specific equipment type. It is a function of the digging equipment capacity and operating safety (Lizotte 1988). It is thus clear that the block size is dictated by the equipment selection and selectivity required and should be determined at the beginning of any open pit design.

2.6. General discussion

From the foregoing it is clear that equipment selection factors should consider the influence of selectivity, especially for selective ore deposits. This requirement is essentially mine driven. It is therefore necessary to briefly review the equipment manufacturer’s development and application strategies.

2.6.1 Manufacturers viewpoints

Any study into equipment selection techniques will be incomplete without taking into account the influence that equipment suppliers have on the ultimate choice. While they may only act in a consulting capacity during the actual selection process, their influence is much larger than it seems. The selection is “limited” to the equipment available on the market, which is dictated by the suppliers’ response to the end users needs. The end users needs are most often dictated by the evaluation criteria applied to a new or existing project. While the goal is usually a selection of equipment that will increase return on investment or even make a low-grade resource payable, the evaluation is typically driven by economy of scale considerations.

The Parker Bay report analyzed the shovel/excavator population on 713 mines and gives an authoritative view of current worldwide trends. (Gilewicz 2001). It can be concluded from the report that although there are movements in the market share between the different shovel types, the momentum is generated by a drive to increase the size of the shovels. Any increase in market share is at the expense of the next bigger category of shovels and a decrease in units is offset by a further increase in capacity. This tendency might be due to an effort to reduce costs in order to utilize lower grade deposits or reserves at a higher stripping ratio. If it is assumed that a significant number of ore bodies can indeed be classified as selective ore deposits, (author's opinion) there is no evidence in the market that effective resource utilization through the correct equipment application plays an influential role in the evaluation criteria applied by the end user. These requirements are thus not passed on to the manufacturer to respond to.

Paterson (2001) discusses the performance of the new larger loading equipment and proves that bigger ultimately is better in terms of cost/ton handled. He uses the classical approach to indicate the positive effect of optimum truck matching. It is however acknowledged that bigger equipment is not always the answer due to production requirements, established pit development or restrictions on capital. An improvement in productivity is still possible when addressing the correct factors such as truck size selection, blasting proficiency, swing angles, truck presentation, spotting time and operator efficiency.

Domaschenz (2001) comments on the influence of bench height on the efficiency of different loading equipment. Every equipment type has a most effective application zone whether it is selectivity, reach, mobility or production rate that is required. Figure 2.4, after Domaschenz*,* indicate that the selected bench height has a large influence on the productivity of hydraulic excavators and face shovels.

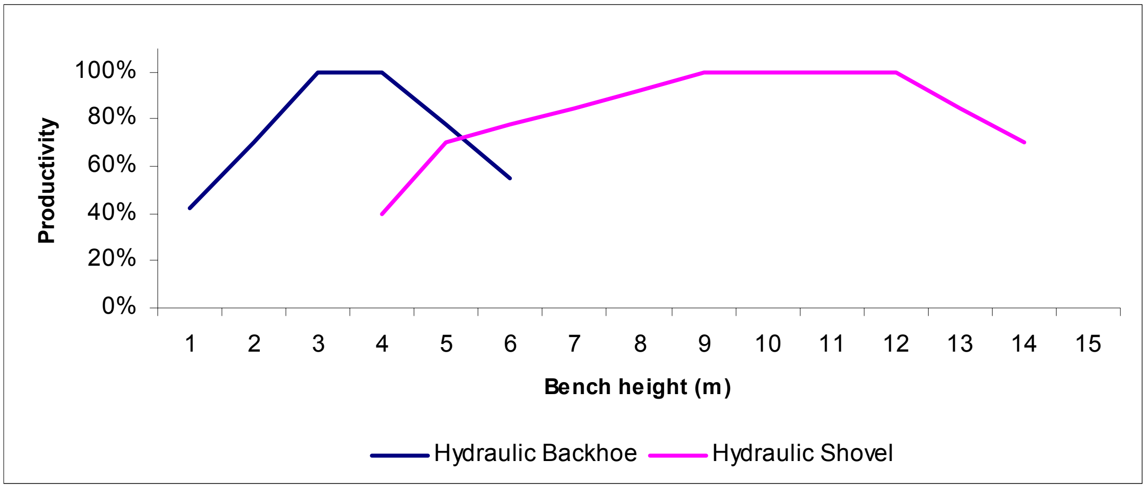


Figure 2.4 Bench height vs. Excavator Productivity of a Liebherr 994 (Domaschenz, 2001)

The suppliers are very much aware that there are different horses for different courses as Wiebmer (1993) indicates. "Each loading tool has its own zone of application. To be a winner you have to choose the right horse for the course. Analyses, not luck will yield the winner for your operation".

Equipment manufacturers ultimately respond to the requirements of the industry. An increase in the population of any shovel type can be attributed to a number of factors. It does not necessary mean that new applications for the shovel have been found. It can merely indicate that the historical application zones have increased. The manufacturers apply a very technical approach to equipment selection and are able to provide the most efficient equipment for any specific requirement. It is often a matter of the right questions not being asked by the end user, rather than the supplier not being able to supply the technical know how. The answers still lies in determining what the critical performance indicator is by applying the Value Chain Costing approach and then use the technical expertise of the supplier to find the most suitable equipment.

2.6.2 Identified development opportunities

It is clear from the available literature that deficiencies exist in the equipment selection process that needs to be addressed. The authors identify various areas for development. Lizotte concludes that it is necessary to formalize the interdependencies between equipment selected and the open pit design parameters. This could be accomplished through;

1. Assigning specific numerical operating ranges to existing equipment,
2. Define the equipment performance as a numerical function of the working site conditions and
3. Derive cost formulas, which relate mining costs to equipment type. This equipment characterization could be associated with a mining specific, equipment classification system.

Grade control is used to maximise the present value of ore production by minimising ore loss and dilution at all stages from mine planning through to milling. 3D modeling of the ore body can assist in evaluating the effect of different bench heights on ore loss and dilution and hence on predicted tonnage and grades. This directly influences resource utilisation. The use of 3D modeling can also be applied to determine the transition from a selective mining operation to a bulk mining operation. A modeled increase in ore losses and dilution can replace subjective assessment. This data can be used to evaluate cost savings in operations, extra process capacity and less processing costs. (Shaw (1992),Dahlstrand (1979)).

2.7. Summary and recommendations for further work

There exists an economic relationship between equipment selection and open-pit design, in extreme cases the processes could lead to conflicting decisions. From the literature study it is evident that the equipment selection process is an integral part of the pit design process and should be incorporated from the beginning. Every equipment type has an optimal application area. Both manufacturers and end users recognize this. Bench height is the one factor that has an equally decisive effect on the utilisation of the resource and the application of the equipment. The bench height is not a result of any parameter but rather the beginning of the process. The recovery can play a vital role in the economic viability of certain projects. Selectivity is addressed in order to improve recovery and dilution and is not a new concept, recognized throughout the literature as having a huge economic influence. In every study certain factors were emphasized in isolation of the overall goal of mine planning, whether it is the matching of a selected shovel with the rest of the equipment fleet or the interaction of the loading tool with the material in order to improve production rate. Eventually one of the factors was definitive and determined the answer to the study.

There is however no evidence that the full potential of resource utilization is quantified in order to determine the optimum bench height and equipment configuration. This must be quantified throughout the whole mining process from the pit layout to the processing plant in order the capture the total economic impact. Only a total Value Chain Costing analyses will be adequate to evaluate this complex interaction of role players to identify the combination that will render the best yield on investors' money.

3 EQUIPMENT SELECTION, SELECTIVITY AND THE MINERAL RESOURCE

3.1. Introduction

Chapter 3 focuses on the influence of equipment selection on the reserve classification and ultimately on the economic value that is added to the project. The principles of resource management encourage a strong focus on resource recovery. The SAMREC code implies that great certainty must exist in terms of ore recovery in order to report on a mineral reserve. The Thabazimbi ore deposit is evaluated before grade tonnage curves are used to determine the recovery, and ultimately the reserve classification, in terms of a selective or massive ore deposit.

3.2. Adding value to the resource base

Macfarlane (2000a) states that the ultimate goal of business can be defined as being “to maximise shareholder value”. He also states that if suppliers of capital do not receive fair return to compensate for the risk they are taking, they will move their capital across national borders in search of better returns. A business must align with the environment in which the business is conducted. In the case of mining companies, the perceived environment is one where margins are relatively narrow, operations are capital intensive and high cost ventures, and risk is not always commensurate with rewards. The objective of a mine or a mining company is to maximise shareholder wealth through effective utilization of the assets, bearing in mind that the principle asset of an operating mining company or resource company is the mineral asset. (Macfarlane. 2000a).

A common approach to quantifying the performance of the company would be to identify profit as the main driver on the short term and to use a discounted cash flow (DCF) approach or net present value (NPV) as the main determinant of the long-term value of the company. Gitman (2000) dispels profit maximization as being the financial goal of the company since "it fails for a number of reasons: it ignores the timing of the returns, the cashflow available to stockholders and the risk". Short-term cashflow can be manipulated by reduction in investment in the future. Reduction in exploration expenditure, timeous waste stripping and a general reduction in flexibility, which is vital in order to reduce internal and external risk, is evidence of this. He states "return and risk are in fact the key determinants of share price, which represents the wealth of the owners of the firm." The implication of this is that risk must be reduced in order to create wealth and that future cashflow must, as far as possible, not be at risk.

Cashflow analyses of mineral projects are usually used to quantify asset value over the long term, through placing a discounted value on future potential cashflow streams. When applying this to open pit scheduling, it tends to direct the focus to the high-grade reserves first. Care should be taken not to exploit the high grade at the expense of the rest of the payable reserve.

The maximum net present value will be obtained through optimal extraction of the payable resource as indicated by the grade tonnage curve

Macfarlane (2000a) emphasizes that the objective of a business is to maximise shareholder wealth through dividends in the short term and through growth in the longer term. Thus, both short and long-term value must be balanced.

Short-term value for a mining company is, in part, determined by;

- The resource and reserve base and the relation between the two.
- The cost level of the operation.
- The operational performance of the company.

These attributes can be found in the balance sheet and income statements of a company where standard ratios are applied to these numbers, which can be used to predict future performance. Macfarlane (2000a) states by example that:

- The value of a company as reflected in the balance sheet is largely in terms of mineral assets and their valuation
- Cost reductions can result in lowering cutoff grades, which increase the value of the mineral assets.

It is now obvious that short-term value can be enhanced through the effective use of the resource base and its conversion to reserves

Longer-term value is assessed through discounted cash flow models of the operation's life. The process to optimise the NPV of a mineral project will require an analysis to determine the following; (Macfarlane. 2000a)

- Optimal operating level within existing constraints
- Defining optimal cost performance in relation to volume
- The resource capability to deliver consistent grade and volume
- Optimal sequence of extraction of the reserve
- Optimal mining mix in terms of grade that will ensure a balance between resource utilization and profitability.

The influence of resource utilization on the long-term value is also evident

"Matching equipment selection and pit geometry to achieve maximum resource utilisation at the lowest cost per saleable ton of product is the challenge to the mining engineer." This problem statement can be expressed differently as **"How does one balance short term profitability with the long term objectives?"** The influence of resource utilization and hence equipment selection and bench height on the value of the business is evident.

The question should be asked as to what is value? It can be described as follows: "Value is determined by the utility combination of benefits delivered to the customer less the total cost of acquiring the benefits. Value is then a preferred combination of benefits (value criteria) compared with acquisition costs." The mining business processes can be arranged and linked in order to form a value chain (Figure 3.1). Each one of these processes must be managed in order to create value and not destroy it.

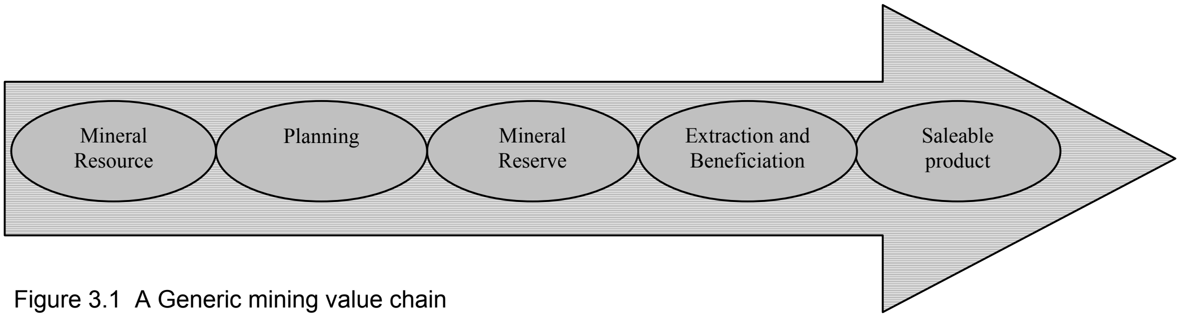


Figure 3.1 A Generic mining value chain

The value chain concept states that it is possible to derive a competitive advantage by arranging value-adding activities in a sequential chain. Both the activities and the linkage of these activities may be a source of adding value. The margin obtained is derived by examining the activities and optimizing them in order to derive the maximum value chain throughput.

3.3. Principles of mineral resource utilization

In order to understand the influence of resource utilization on the mining value chain, one must see it in the whole context of Mineral Resource Management (MRM). MRM is an integration of key functions (survey, planning, geology and evaluation, production, beneficiation and the potential market), which ensures that value is added and risk reduced through the whole value chain. This integration should be combined with the financial function and the strategic direction of the company in order to maximise shareholder wealth. This total integration is a linkage between strategic and operational planning through a translation of company goals into operational mining plans.

Macfarlane (2000b) discusses the reason for the integration of these processes into a MRM function:

- Margin squeeze: Falling or static commodity prices in most sectors of the minerals industry have had a global effect. The result of this has been to effectively raise cutoff grades, thereby sterilizing resources.
- Quality deposits: Large, accessible, high-grade deposits are not easy to come by. Those currently in production require an increasing amount of innovative skill to maintain margins while new prospects tend to carry with them economic, technical and political risk.
- Global competition: Industry cost curves illustrates a downward trend. While this sends out a positive signal, the question arises whether this is the only objective that the company should follow.
- Investor's profiles and expectations: The profile and expectations of investors have changed. They are looking for short-term growth in value, manifested in cash earnings and reinvestment. This will affect the way mineral assets are managed.
- Due diligence: Mining companies need to exercise due diligence in the management of the Resources and Reserves. This means working in accordance with the SAMREC code when reporting Resources and Reserves.

Mineral Resource Management was borne from a need to address the above-mentioned challenges through increasing value and reducing risk. MRM ensures that value is added on the short term through:

a) Growth in the Resource and Reserve, trough application and management of cutoff grades
b) Improvement of operational performance through cost, dilution and recovery improvement.
c) Optimization of extraction and mining mix, in terms of grade. (Grade control)
d) Exploitation of opportunities that further enhances value.

e) Quality assurance in the transparent reporting of Resources and Reserves.(reduction of investment risk)

Long-term value will be added through:

a) The development of extraction plans which realise the required balance of profitable life, NPV and IRR.
b) The development and application of a dynamic cutoff policy, which realises the long term goal of the company
c) The design and selection of mining methods and technologies which will improve operational effectiveness and ore recovery
d) The identification of investment opportunities, which will realise future growth in value of the asset. (Making marginal deposits economical)
e) Balancing short and long term objectives, and the prevention of sub optimal solutions being imposed, which could compromise long-term viability.

It is important to determine the linkage between short and longer-term value to make sure that the one does not compromise the other. This is the purpose of resource management, not only ensuring that the linkage is intact but that value is created and not destroyed. In order to address all these issues, it is important to know the resource. The grade tonnage curve can be applied to analyze the resource and will be discussed in more detail later.

Due to the nature of the ore body, commodity prices, available market etc., all initiatives will not realise the same advantage. It is thus necessary to determine the key value drivers, those action or initiatives that will add the most value to the total value chain. These optimizations can be done on either the process or the linkage between the processes. Cash flow analyses should be accompanied by sensitivity analyses to determine these key value drivers. Although the drivers will vary between commodities and from operation to operation, some generic drivers include price, cost, dilution, recovery and volume. From these drivers it is apparent that resource utilization can be singled out as the key value area in the total Resource Management domain. The impact extends through most of the processes in the value chain as indicated in figure 3.2.

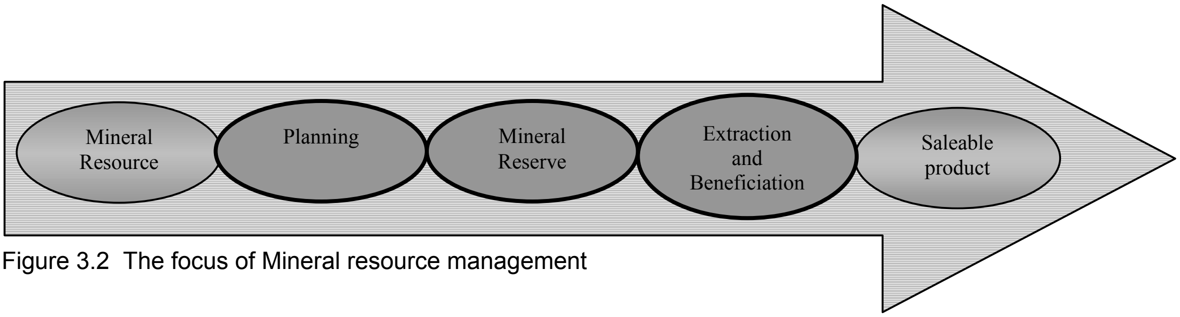


Figure 3.2 The focus of Mineral resource management

By establishing the influence of equipment selection and pit geometry on resource utilization, it will be evident that the impact extends beyond the initial anticipated boundaries, through the whole value chain, effectively adding value and reducing risk and thereby playing a undeniable role in total Resource Management.

3.4. Resource and Reserve

The SAMREC Code sets out minimum standards, recommendations and guidelines for Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves in South Africa. The main principles governing the operation and application of the SAMREC Code are transparency, materiality and competence.

Public Reports dealing with Mineral Resources and/or Mineral Reserves must only use the terms set out in Figure 3.3.

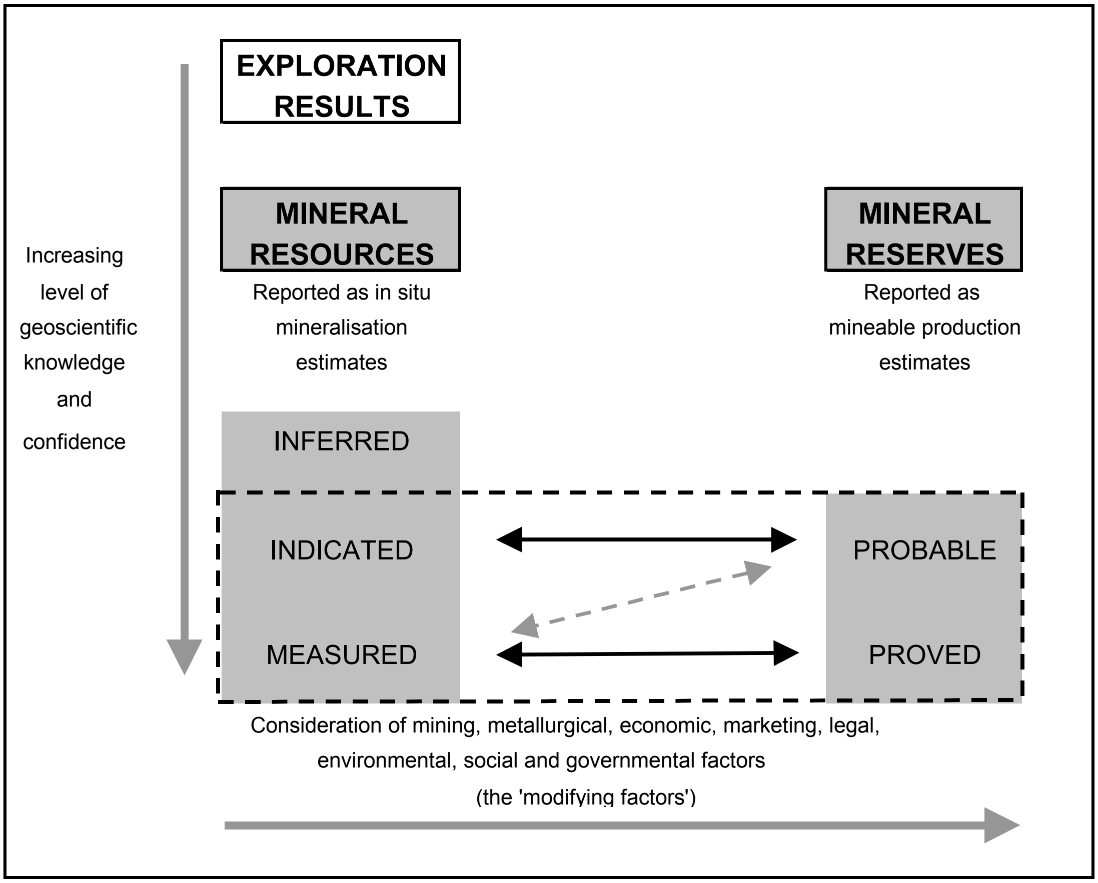


Figure 3.3 Relationships between Mineral Resources and Mineral Reserves (SAMREC, 2000)

Figure 3.3 sets out the framework for classifying tonnage and grade estimates so as to reflect different levels of geoscientific confidence and different degrees of technical and economic evaluation. Mineral Resources can be estimated on the basis of geoscientific information with input from relevant disciplines. Mineral Reserves, which are a modified sub-set of the Indicated and Measured Mineral Resources (shown within the dashed outline in Figure 3.3), require consideration of factors affecting extraction, including mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors (‘modifying factors’), and should in most instances be estimated with input from a range of disciplines.

Mineral Resources are defined as follows;

"A 'Mineral Resource' is a concentration [or occurrence] of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable and realistic prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, estimated from specific geological evidence and knowledge, or interpreted from a well-constrained and portrayed geological model. Mineral Resources are subdivided, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated and Measured categories."

and Mineral Reserves;

"A 'Mineral Reserve' is the economically mineable material derived from a Measured and/or Indicated Mineral Resource. It is inclusive of diluting materials and allows for losses that may occur when the material is mined"

The evaluation techniques used (including, where relevant, the block sizes) and the key assumptions made in arriving at the estimate must be disclosed. The term 'economic' implies that extraction of the Mineral Reserve has been demonstrated to be viable and justifiable under reasonable financial and mining recovery assumptions.

Mineral Reserves are reported as inclusive of marginally economic material and diluting material delivered for treatment. It is clear that a thorough understanding of the expected mining recovery and dilution is necessary at this stage of the evaluation to enable the competent person to accurately report on the mineral reserves. From these definitions it is clear that the assumed recovery and dilution plays a vital role in the calculation of the reserve base. It is the purpose of the mine planning section to apply these factors and determine how much of the resource can be reported as economical reserves.

3.5. Evaluation of Iron Ore Deposits

The geology of iron ore deposits is so diverse that all sorts of geologic and geophysical techniques are used in the exploration and evaluation. Also their geographic distribution is so wide that every continent has important productive areas. The emphasis on Resource Management has made a detailed geological study of the deposit increasingly important, for only these detailed studies can provide the information, which is of vital importance to proper evaluation and profitable exploitation. Characteristics such as mineralogy, texture, concentratability, grindability, manner of distribution of ore types etc. are investigated as well as other more traditional factors such as production costs, markets and taxes. Only by complete monetary appraisal of each item can the long-term value of different deposits be determined. Table 3.1 lists the more important characteristics of an iron ore deposit, which enter into the evaluation according to Ohle (1972). A successful evaluation on these technical requirements is essential if an iron ore deposit is to be classified as an economic ore body. It is however not necessary for a deposit to be perfect in every regard, none are. Nearly all deposits have strong factors but all of them also have weak points.

Table 3.1 Characteristics of an iron ore deposit

Geological Factor	**Description**
1. Type and Grade	Impacts on the market specification and beneficiation required
2. Tonnage	The life of mine, capital required, recuperation schedule.
3. Grain Size	Liberation of ore mineral, elimination of impurities.
4. Grindability	Energy required to reduce the ore to concentrating size
5. Mineralogy	Magnetite, hematite, goethite-effect on the ability to separate the impurities in processing
6. Distribution of ore types	Grades, textures, mining recovery, can selective mining be done
7. Depth and nature of overburden, shape of the ore body.	Sand and gravel or rock, surface mining vs underground.
8. Shape and attitude of the ore body	Tons per vertical meter and effects on stripping ratio
9. Location	Topographic effects, climate.

The most significant factors will be discussed in the light of equipment selection.

3.5.1 Ore type and grade

Ore type and grade are interrelated but is not the same thing because the former also involves the amenability of the ore to various kinds of beneficiation. When discussing the grade, reference should be made to the iron content, structure and the amount of impurities and associated elements present. In iron ore the presence of an unusually high amount of some minor element usually reduces the marketability of the ore. In the iron ore trade various ore deposits are classified according to the process used to upgrade the crude to marketable quality. It is important to note that the run of mine grade can be influenced by the amount of dilution generated during mining activities such as blasting and loading. The degree to which selective loading can be achieved at the face thus influences the type of beneficiation required and consequently the classification of the ore type.

3.5.2 Tonnage

Tonnage is important as it governs the practical size of the mining operation. When reporting tonnage a differentiation should be made between the resource and the reserve base as stipulated by the SAMREC code. Significant long-term value will be added through the conversion of resources to reserves. Mining recovery through selective mining can have a significant impact on the reserve base of a selective ore body. If high capital investment is required the life of mine should be sufficient to allow a depreciation rate that does not raise the capital charge per ton to a level where total cost becomes uneconomic.

3.5.3 Mineralogy

Mineralogy is the study of the properties, composition and occurrence of minerals. Mineralogy plays an important role through the total production process at a mine, as the crystal structure and mineralogy will determine properties of the ore. These properties can influence variables such as hardness, which will again, influence aspects such as the crushing/ milling properties and eventually the reactivity and extraction of the metal during the metallurgical/beneficiation processes. A clear understanding of the host rock mineralogy and thus influence of the host rock on the total mining process, can also assists in the quantification of advantages gained through an increase in selective mining.

3.5.4 Distribution of ore types in the deposit

It is probably true that few deposits being worked are entirely homogeneous. All having variations along the bedding and across the bedding in the crude grade, mineralogy, grindability, liberation size, concentrate grade and other factors. Since beneficiation plants operate most efficiently on uniform feed it becomes extremely important to know the distribution of ore types within the deposit and being able to have control over the quality of the feed to the plant. This is possible through correct blending and just as important, being able to limit the amount of contaminants during the mining activity. During the development and mining stages of an iron ore deposit, the geologist can make a significant contribution. Detailed mapping and sampling often indicate that various ore types are present and provide a general knowledge of their distribution so that the chances for selective mining or controlled blending can be evaluated. The influence of equipment selection on the ability to respond to these signals will be discussed later but it is important to note the importance of being aware of equipment selection in these early stages of the resource definition.

3.5.5 Depth and nature of the overburden and the shape of the ore body

The depth and nature of the overburden plays a significant part in the economic evaluation of any resource. It determines the volume of material to be moved in order to expose the ore body and consequently the timing and cash flow of the operation. The type of overburden will have a direct impact on the production cost, which will vary widely according to whether the overburden is sand and gravel or rock. The amount of overburden and thus stripping ratio will further complicate the equipment selection process if selective mining is considered. The high stripping ratio will require high volume production machines, which will not support the requirements of selective mining equipment. A combination of different machines should be considered in this case. More important however is the shape of the ore body. The higher the angle at which the ore body dips, the easier it is to separate the ore from the waste during the loading action. Depending on the type of equipment utilized, the bench height should not have a significant influence on the ability to perform selective loading on steep dipping ore bodies (see figure 3.4). However, if the ore body is dipping at a flat angle, the selective loading action becomes very complicated and the bench height and equipment selection could make a significant impact on the mining recovery and thus the conversion of resources to reserves. Every ore body is distinct and the construction of grade tonnage curves and block evaluations on different bench heights could be used to determine whether a material impact could be made on the economic evaluation of the reserve. The situation will continue to increase in complexity as the angle decreases until a dip is attained where a horizontal distinction can be made between ore and waste and the bench height can be adjusted to suite the position of the ore body.

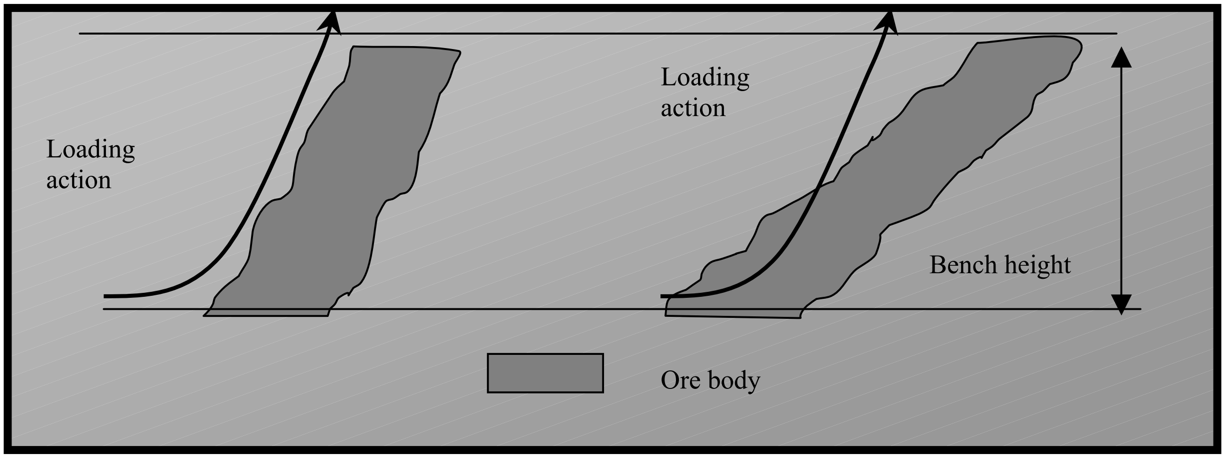


Figure 3.4 Influence of the ore body dip angle on the loading action.

3.6. Thabazimbi Iron Ore Deposit

With a crustal average of 5% by mass, iron is one of the most abundant elements in the earth's crust and it can be separated with relative ease from other elements to which it is bound in nature to form a gray material. Iron was one of the first metals used by mankind and presently is the metal most widely used. The more commonly exploited iron-bearing minerals, with their respective compositions and iron contents are given in table 3.2.

Table 3.2 Commonly exploited iron-bearing minerals

Ore type	Chemical composition	% Fe content
Magnetite	$FeO.Fe_2O_3$	72% Fe
Hematite	Fe_2O_3	70% Fe
Goethite	$FeO.OH$	61% Fe
Lepidocrocite	$FeO.OH$	61% Fe
Siderite	$FeO.CO_2$	48% Fe
Chamosite	$3FeO.Al_2O_3.2SiO_2.6H_2O$	35% Fe

The iron deposits of South Africa can be broadly divided into the following geological associations:

1. Banded Iron Formations (BIF)
2. Magmatic Deposits
   -in basic rocks
   -in acidic rocks
   -in alkaline rocks
3. Gossans and residual deposits
4. Lode, vein and replacement deposits.

Of these the BIF deposits are by far the most important economically.

The Thabazimbi Mine, which lies in the Northern Province some 200 km north-northwest of Pretoria, has been operating since 1934 and was the major source of iron ore in South Africa until 1958 when its production was surpassed by Sishen.

3.6.1 Geological setting of the ore bodies

The iron ore bodies of Thabazimbi Mine are located within the Penge Formation, situated at the top of the Chunniespoort Group. The Penge Formation consists of approximately 350m of BIF or banded chert and hematite rhythmites. The basal unit of the Penge Formation consists of chert-rich carbonaceous shale that reaches a maximum thickness of 15m. The iron ore bodies occur in the 80m thick iron oxide rhythmites of the Penge formation. The ore occurs as irregular, tabular ore bodies long a strike length of 12km with sterile gaps of iron formation in between. These ore bodies wedge out laterally and thickness vary between 2 and 100m with an average of 20 m. In depth these ore bodies pass laterally into carbonate-hematite and talc-hematite (see figure 3.5). In the Thabazimbi area the Penge Formation dips to the south at 40° to 50°. Waterberg-age tectonism resulted in faulting, which duplicate the ore zone, while subsequent differential weathering formed two prominent mountain ranges, the Northern and Southern Ranges, with a smaller Middle Range in between. (Van Deventer et al 1986). The faulting is described by Strauss (1964) as east-west-trending, high angle thrust faulting. Post-karoo normal faulting and the intrusion of dolerite dykes have further disrupted the ore zone (Van Deventer et al. 1986)

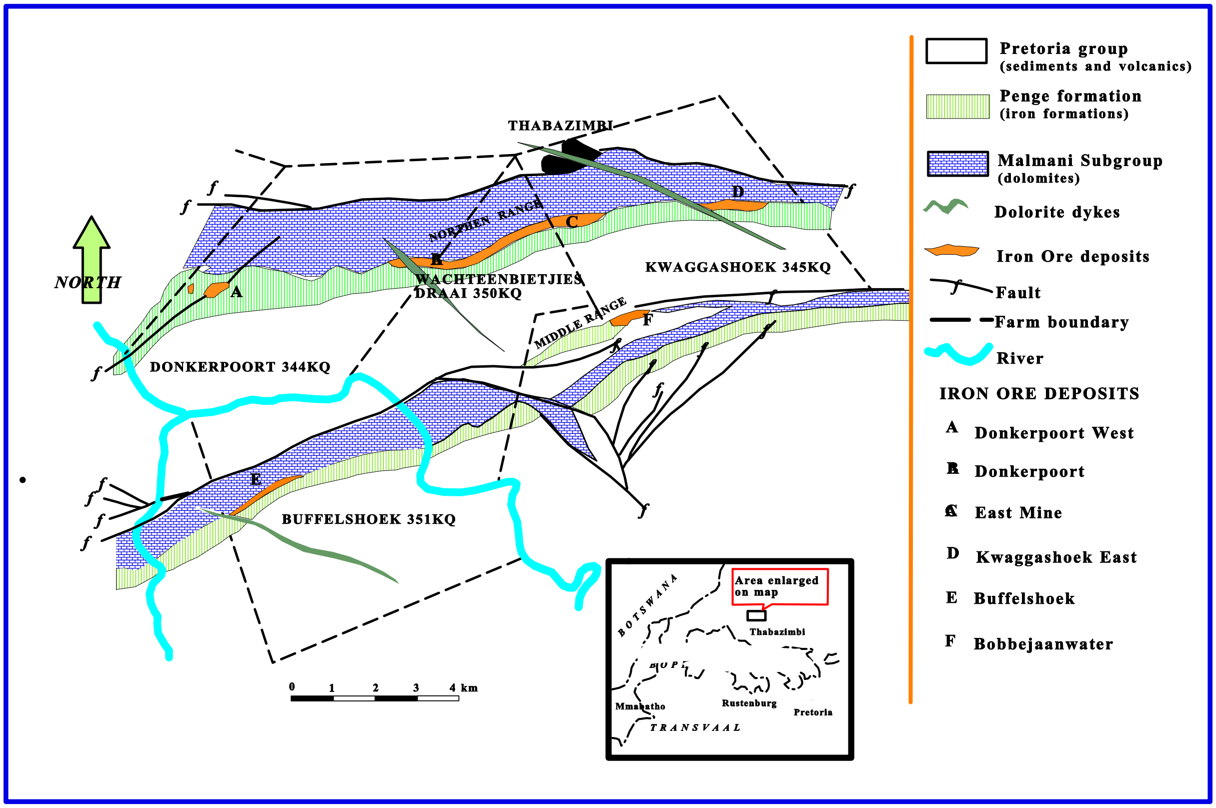


Figure 3.5 Geological setting of Thabazimbi ore deposits (Van Deventer et al. 1986)

3.6.2 Lithology

The ore bodies of the Northern Range have an irregular tabular shape and are usually in direct contact with the footwall shale, which separates them from the underlying dolomites. Most of the ore is brecciated and consists of primary hematite fragments set in secondary hematite matrix. The proportions of primary and secondary hematite in the ore vary and are influenced by the amount of chert in the rock and the thickness of the original hematite rhythmite bands. Lenses of primary iron formation are often present in the ore and tend to decrease the overall grade during bulk mining. This dilution can be excluded from the run of mine product through selective mining. The ore bodies average 18-25m in thickness and occur at the base of the banded iron formation, which has a total thickness of between 230 and 305 m. A highly decomposed diabase sheet is present some 90 m above the footwall shale.

3.6.3 Ore Characteristics

The following features characterize the Thabazimbi ore bodies:

- Each hematite ore body is surrounded by a distinct oxidation halo that effects not only the iron formation, but also the underlying shale and dolomite units
- Ore bodies on the southern range are smaller than on the northern range – the northern range was subjected to more intense leaching processes
- Ore bodies have an irregular tabular shape and are usually in contact with the footwall shale, which separates them from the underlying shale.
- Most of the ore is brecciated and consists of primary hematite fragments set in secondary hematite matrix.
- Lenses of primary BIF are often present in the supergene enriched ore
- The upper contact of the ore body is in most instances gradational.
- The ore bodies average 18-25m in thickness (wedge shape).
- Close to the present day surface, the high-grade ore is hard, compact, finely laminated and massive containing up to 68% Fe.
- At depth the ore becomes softer and more friable and passes into talc-hematite or carbonate-hematite as well as brecciated calcite ore.
- The ore bodies are frequently brecciated due to karstic solution collapse of the underlying dolomites and undulose due to irregular karstic surface.

The resource and reserve statement on Thabazimbi Mine reports on four different orebodies. All of these resources have been engineered to reserves using the current equipment limitations and assumptions. Table 3.3 summarises the tonnage in each of the geographical mining areas. The significant difference between the total resource and in pit resource is due to the high stripping ratios required to expose the ore. The “in pit resource” is inclusive of all the hematite ore resources within the economic pit boundaries with an iron grade above 50%. This resource does not include dilution. The reserve is an indication of the amount of ore that can be recovered within the specified qualities and includes marginally economic material as well as dilution. These figures indicate recovery and dilution at a 12-meter bench height. It is clear that potential exists to increase the reserve base through more effective ore recovery.

Table 3.3 Thabazimbi Resource/Reserve base

Pit		Total Resource	In Pit Resource	Reserve @ 12m bench height
Donkerpoort	DPN	15.49 Mt	2.76 Mt	1.76 Mt
Buffelshoek West	BHW	9.98 Mt	8.99 Mt	5.24 Mt
Donkerpoort West	DPW	15.91 Mt	11.40 Mt	7.51 Mt
Kwaggashoek East	KHO	6.12 Mt	5.81 Mt	3.92 Mt

The effective recovery can be simulated through the construction of grade tonnage curves at different bench heights.

3.7. The Grade Tonnage Curve and Mining Recovery

3.7.1 The Grade Tonnage Curve

A grade tonnage curve expresses the proportion of the ore body above a series of cutoff grades and also depicts the average grade of the material above the cut-off grade. This curve can be seen as the thumbprint of the ore body and can be used to determine the influence of various actions to increase the recovery of the resource. The estimation of grade tonnage curves is a complex geostatistical problem and will not be discussed in detail. It is however important to evaluate the influence of the block size on the result of the grade tonnage curve.

As a direct result of volume variance relationships, larger blocks will have a different grade tonnage relationship compared to smaller blocks, since larger blocks will have a lower variance. A schematic representation showing typical grade tonnage relationship for different block sizes is shown in figure 3.6. It is apparent that the larger the block the lower the average grade above cut-off. Less obvious is the tonnage behavior, larger blocks have tonnage profiles characterized by progressively steeper transitions between lower grade and higher grade ores with increasing cutoff grades. The limiting case is that of a single block representing the ore body, which is either totally above or totally below cut off grade. Understanding of the general relationship between grade tonnage curves with respect to block size allows one to assess whether the various relationships are consistent.

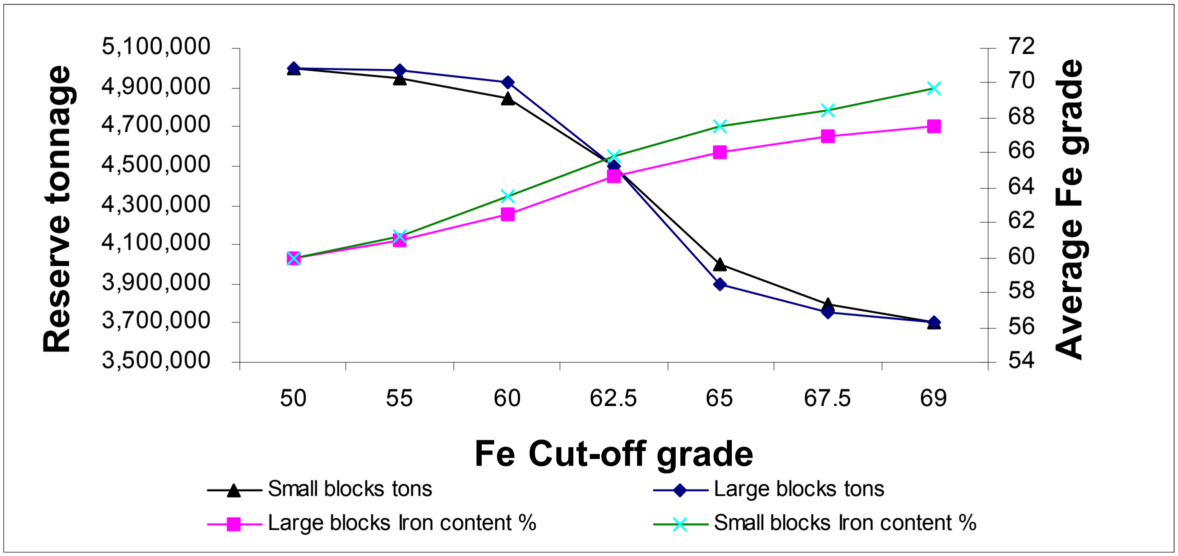


Figure 3.6 The volume variance relationship

There is a practical limit that must be considered when considering block size and selectivity as suggested by grade tonnage curves. A grade tonnage curve assumes the ability to select material based on the block size, which means to realize the true potential indicated by the curve, the equipment must be able to select and separate blocks of the size assumed by the grade tonnage curve. If this is not the case, the curve will present a highly artificial view of the ore body and does not convey much true information on the selectivity.

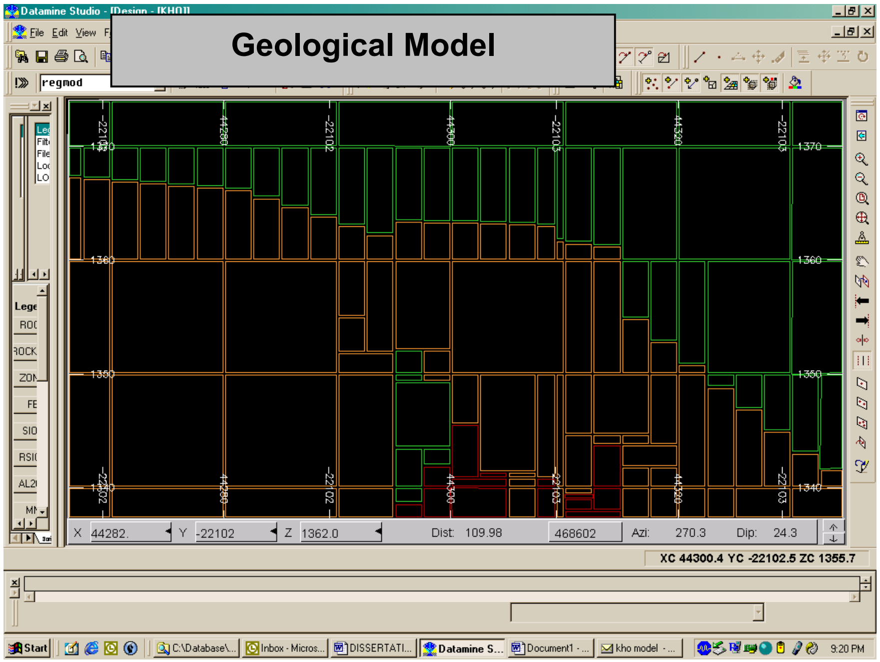
During the pit optimization phase it is necessary to assume certain mining recoveries. These assumptions must be a true reflection of the ability of the equipment because it directly influences the revenue that will be generated by the in-situ ore. The revenue that is generated will ultimately determine the size of the pit and thus the total resource utilization.

The grade/tonnage curve is a helpful tool because it allows the derivation of

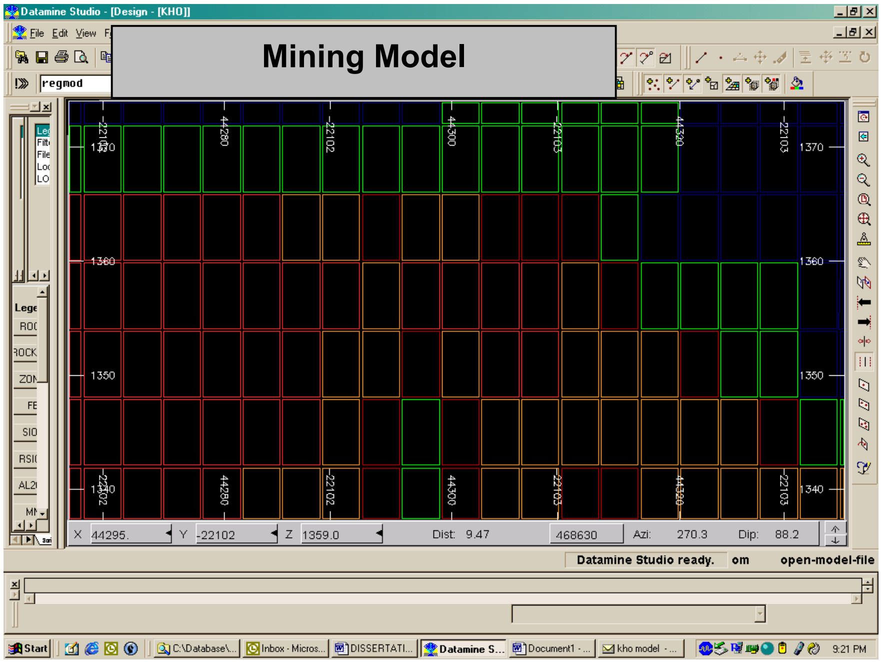
- A cutoff grade,
- The average mining grade of the resource above the cutoff and
- The tonnage available above the cutoff.

3.7.2 Simulating Mining Recovery

The simulation is based on imitating the mining recovery and dilution that will occur during the loading action. The Datamine Studio software system was used to manipulate the geological block model to generate a mining model (see figure 3.7). The mining model consists of homogenized blocks, each representative of a mining unit. A mining unit is the volume of ore on which a decision can be made whether to treat as waste or ore. Once the mining model has been created the grade tonnage curve will be used to calculate the mining recovery and cut off grade for different bench height scenarios.



Geological Model



Mining Model

Figure 3.7 Geological model compared to a mining model

The actual dipper measurements for each shovel type were used as a base for determining the appropriate block size. A bench height increment of 3m was selected. It was thought necessary to distinguish between the wheel loader and the other shovels since the dipper dimensions vary considerably as can be seen in table 3.4. Sensitivity analyses however indicated that horizontal dimensions of the block do not have as significant influence as the volume of the block (see appendix A). Since the volumes of the blocks differ by less than 1%, the decision was made to use horizontal dimensions of 3.5mx3.5m as depicted in table 3.4.

Table 3.4 Dipper measurements

Shovel type	**Capacity**	**Height**	**Width**	**Depth**
Rope shovel	$19m^3$	3500mm	3400mm	3500mm
Wheel loader	$16m^3$	2500mm	5600mm	2200mm
Hydraulic shovel	$16m^3$	3500mm	3800mm	3650mm
Hydraulic excavator	$15m^3$	3400mm	3500mm	2600mm
Block dimensions for the evaluation				
All shovels		3000mm	3500mm	3500mm

The procedure depicted in figure 3.8 was followed in creating the mining model and construction of the grade tonnage curve.

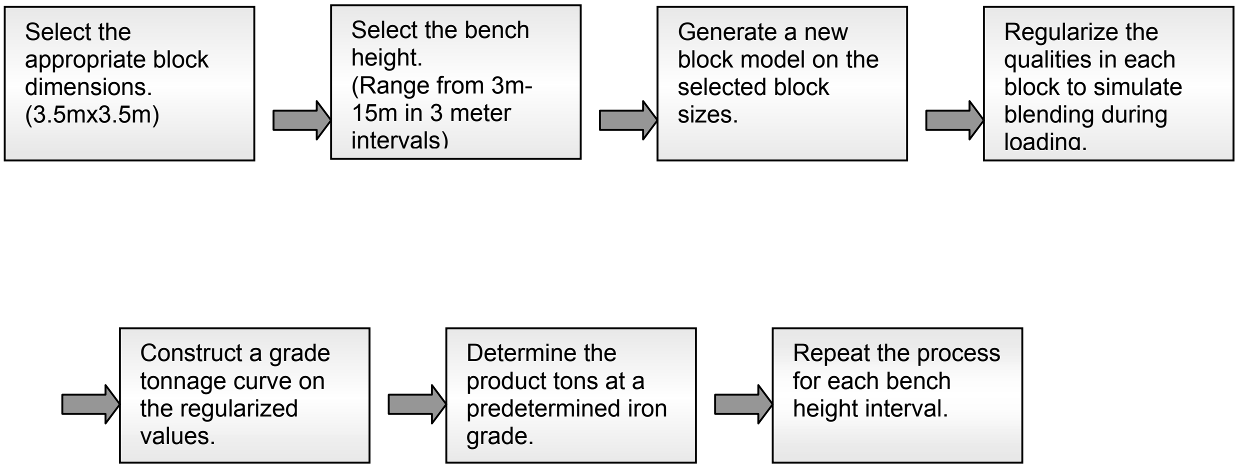


Figure 3.8 Simulation procedure

3.7.3 Simulation Results

The grade tonnage curve for the Buffelshoek-west pit is shown in figure 3.9. An average iron grade above cut off value was selected as 62.5%, i.e. the product value (A). The intersection of this line and the grade line (B) indicates the required cut off value (E), to achieve the product value. The intersection of the cut off value and the tonnage line (C) indicates the available tons of material above the cut off value (D). Each set of lines represent a different bench height and it is clear that significant potential exists for increased recovery (refer to appendix B for full simulation results).

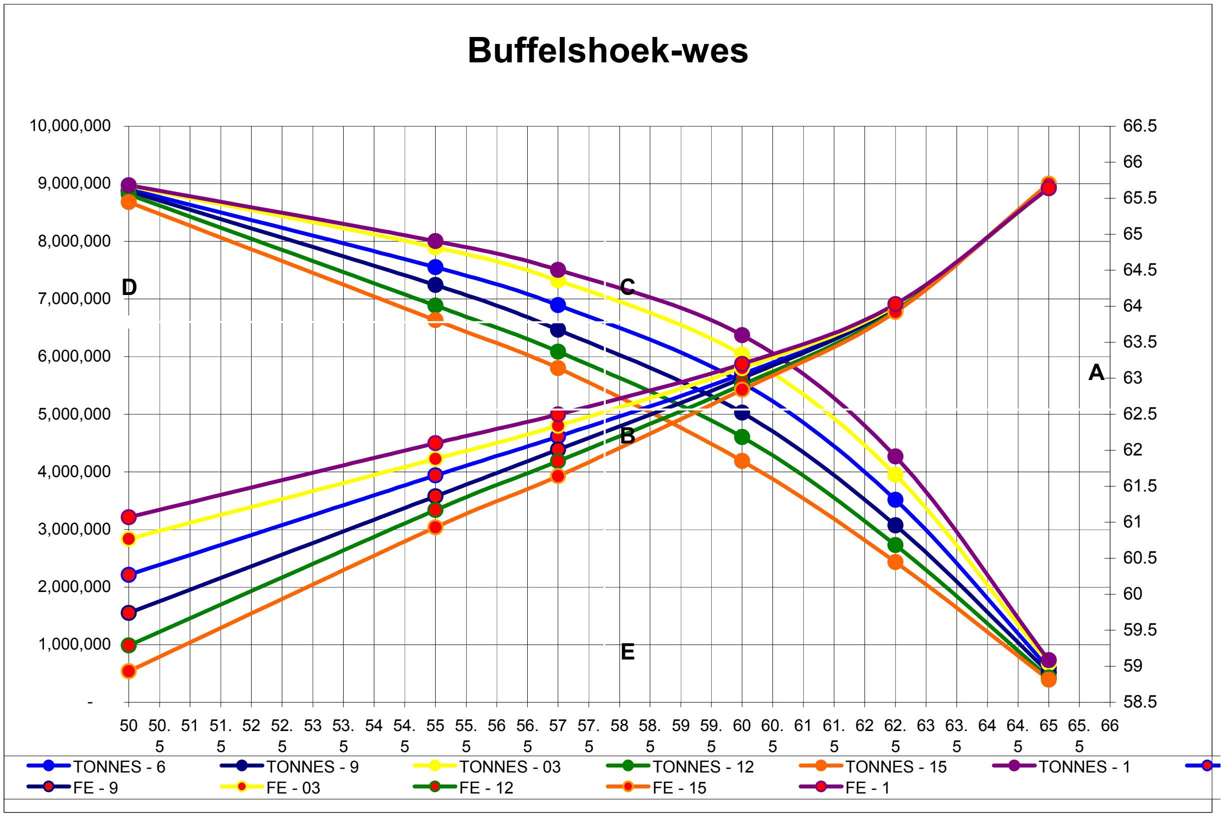


Figure 3.9 Grade tonnage curve – Buffelshoek-west

Figure 3.10 shows the percentage decrease in reserve at each increase in bench height. The decrease in reserve from 1m to 3m bench heights is rather small at 3%. A consistent decrease of on average 8% is shown for each interval thereafter. The influence on waste stripping is graphically presented in figure 3.11.

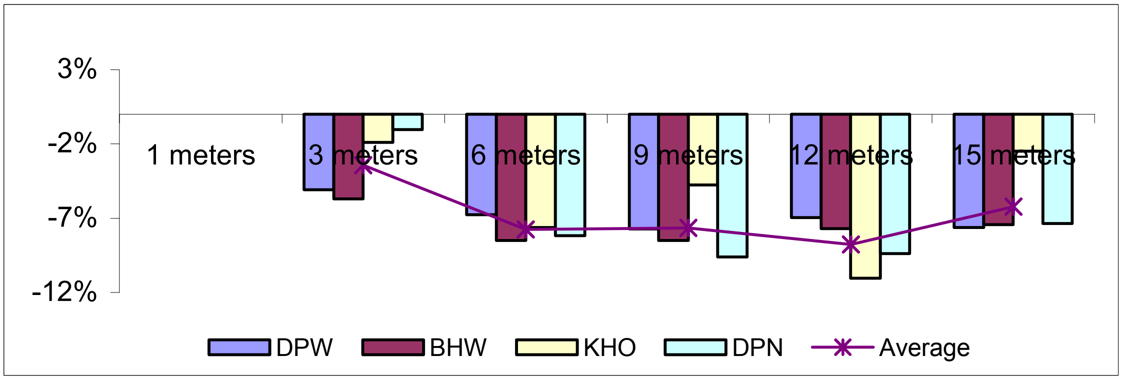


Figure 3.10 The incremental percentage decrease in reserve with an increase in bench height

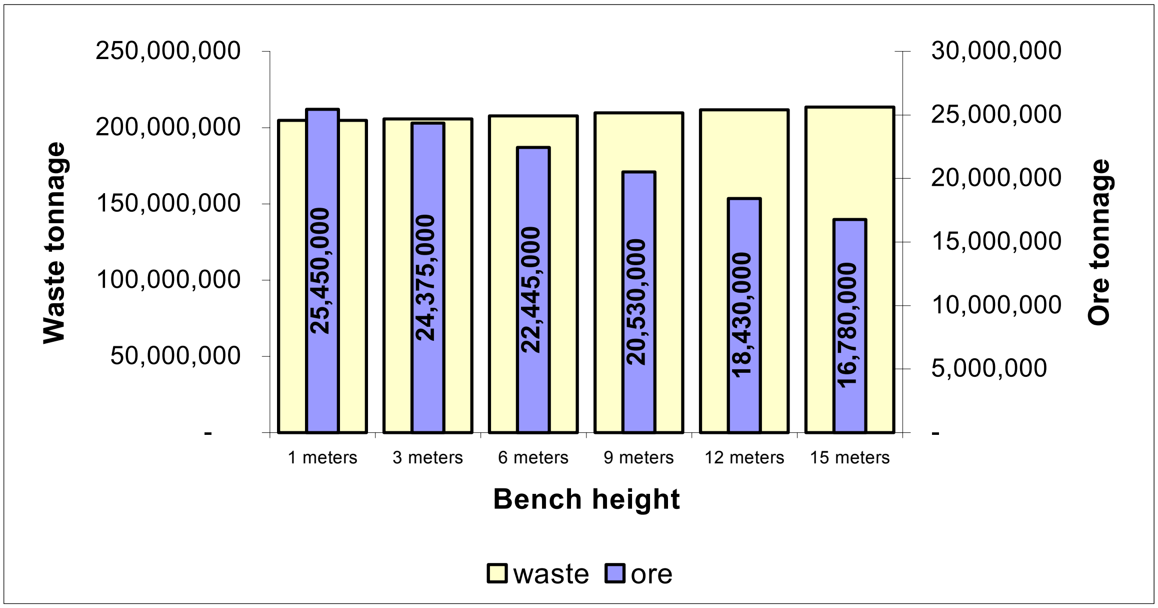


Figure 3.11 The influence of decreased ore recovery on required waste stripping

The potential or increased recovery will differ for each ore body because of the fact that the geometry of the ore bodies differs (see table 3.5). The results indicate that a mining loss of between 12% and 15% are realized even at a bench height of only 3m. This loss increases to 21% in the Buffelshoek-west pit. The iron-grade distribution has to be studied to fully understand the nature and potential of each ore body. If dilution occurs on the footwall side where shale and dolomite with no iron content is mixed with high grade ore, the average will decrease very quickly, causing high volumes of low grade material in the low 50% range to be lost. If dilution occurs on the hanging wall side, banded iron formation with a relative high iron grade can be mixed in high volumes before adversely affecting the average grade. These scenarios are caused by the mining direction and deployment strategy. The geometry of the ore body and the mining direction plays a pivotal role in the reserve classification. The reason for the low recovery in the Buffelshoek-west pit is due to low-grade lensic intrusions into the high-grade hematite as indicated in figure 3.12. This can be addressed, if at all possible, through even more focused selective mining efforts.

Although this seems to be a significant difference, it might not always be the case. In order to determine whether the ore body should be treated as a massive or selective ore body, it is necessary to determine if this has a material influence on the economic viability of the project.

Table 3.5 Potential increase in ore recovery

Pit	In Pit	Reserve @ 15m Bench height	Reserve @ 3m Bench height	Potential increase in Reserves
Donkerpoort	*2.76Mt*	*1.58 Mt*	*2.43 Mt*	*54%*
Buffelshoek-West	*8.99Mt*	*4.68 Mt*	*7.10 Mt*	*52%*
Donkerpoort-West	*11.41Mt*	*6.73 Mt*	*9.70 Mt*	*44%*
Kwaggashoek-East	*5.81Mt*	*3.79 Mt*	*5.15 Mt*	*36%*

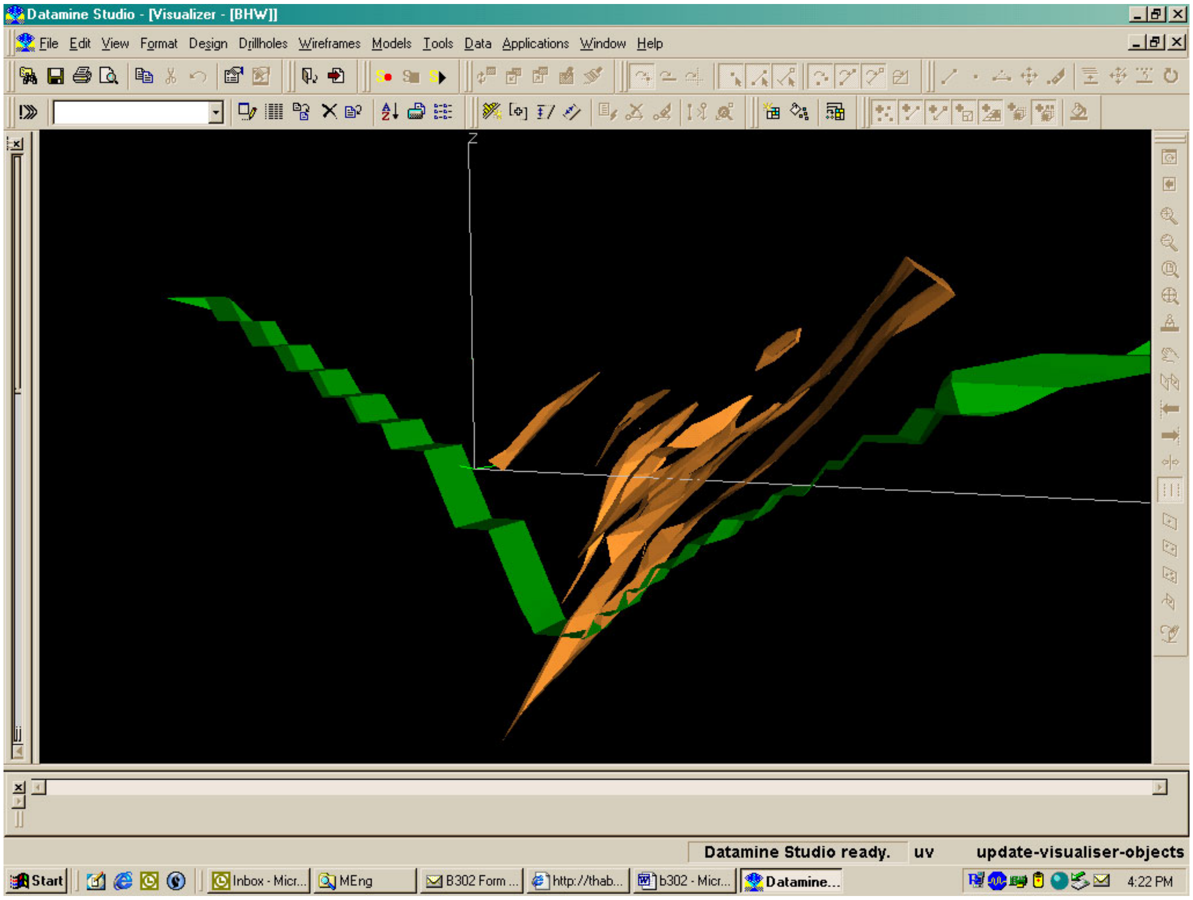


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Figure 3.12 A north-south profile showing the pit layout in green and the lensic nature of the ore body in orange.

3.8. The interpretation of a massive or selective ore body

The benefit of increased recovery is not always as obvious as in the case of the Thabazimbi reserves. It is necessary to evaluate the potential of increased recovery financially before the complete economic study is attempted. This can be done through the concept of financial materiality. It was stated earlier in the chapter that the ultimate goal of a business is to maximise shareholder value and that the value of a company as reflected in the balance sheet, is largely in terms of mineral assets and their valuation. The influence of an increase in mining recovery on the reserve base has been proven. It is therefore possible to evaluate the impact of any change in the mining recovery in terms of financial measures and in particular in terms of materiality.

The concept of materiality has been discussed on numerous forums. It is most commonly described as:

“ the magnitude of change in a financial measure, that makes it probable that the judgment of a reasonable person would have been changed or influenced by the result” (Reyhl 2001).
and also:
“ the change in results could influence the economic decisions of users taken on the basis of the financial statements” (Højskov 1997).

But what is the materiality level? A survey in profit driven companies indicated that the financial analyst's materiality level was about 2½ - 3% of the net profit before extraordinary items and tax (Højskov 1997). Marx (1998) suggests using the following (table 3.6) as a guideline to determine whether the influence is material:

Table 3.6 Guideline for determining financial materiality

Measure	
Turnover	1%
Gross Profit	2%
Net income	5-10%
Total assets	1-2%
Equity	2-5%

According to Marx, materiality needs to be based upon the most appropriate criteria for the entity that will provide a stable basis. It can be a single indicator or a combination thereof.

It is now possible to state that when the increase in the reserve base due to better recovery poses the potential to be of such magnitude that the economic evaluation changes materially, the reserve can be classified as a selective ore body. When the potential does not exist to improve the economic evaluation materially, the ore body should be classified as massive and the equipment selection should pursue the combination of equipment with the lowest operating cost

This statement should form the start of any mine design process. The equipment selection philosophy is determined here and the whole selection and evaluation process will follow this direction.

The results of the potential study done on the Thabazimbi ore bodies are summarised in table 3.7 in terms of the materiality concept described above.

Table 3.7 Economic impact on Thabazimbi ore deposits

Pit	Reserve increase	Net Income increase	Gross profit	Natural assets
Donkerpoort	*31%*	*31%*	*65%*	*31%*
Buffelshoek-West	*31%*	*31%*	*49%*	*31%*
Donkerpoort-West	*25%*	*25%*	*50%*	*25%*
Kwaggashoek-East	*23%*	*23%*	*46%*	*23%*

The financial indicators are rough estimates that were calculated to determine the economic potential. These figures are sensitive to the production costs and shows larger sensitivity at lower profit margins. These figures indicate that the Thabazimbi ore bodies can be classified as selective ore bodies since significant economic potential exists to add value through better ore utilization.

3.9. Summary

It became evident from the discussion that any company exercising their mineral rights has an obligation to manage the extraction of the resource in such a way that the maximum value realizes. This can be achieved, in part, through an increase in resource to reserve conversion. Each mineral deposit will demonstrate different potential for increasing the reserve base. If, according to the definition of materiality, a material difference can be made, the project should be classified as a selective deposit and the equipment selection should be determined by the advantages gained from selective mining (Refer to figure 4.11).

If however a material increase in the value of the project cannot be proven, bigger remains better and the lowest production cost should play a significant role in equipment selection process. The process of determining whether the resource should be classified as a massive or selective ore deposit is summarized in figure 3.12. The mine planning process must make provision for the resource evaluation before the block modeling starts, as indicated in figure 6.4.

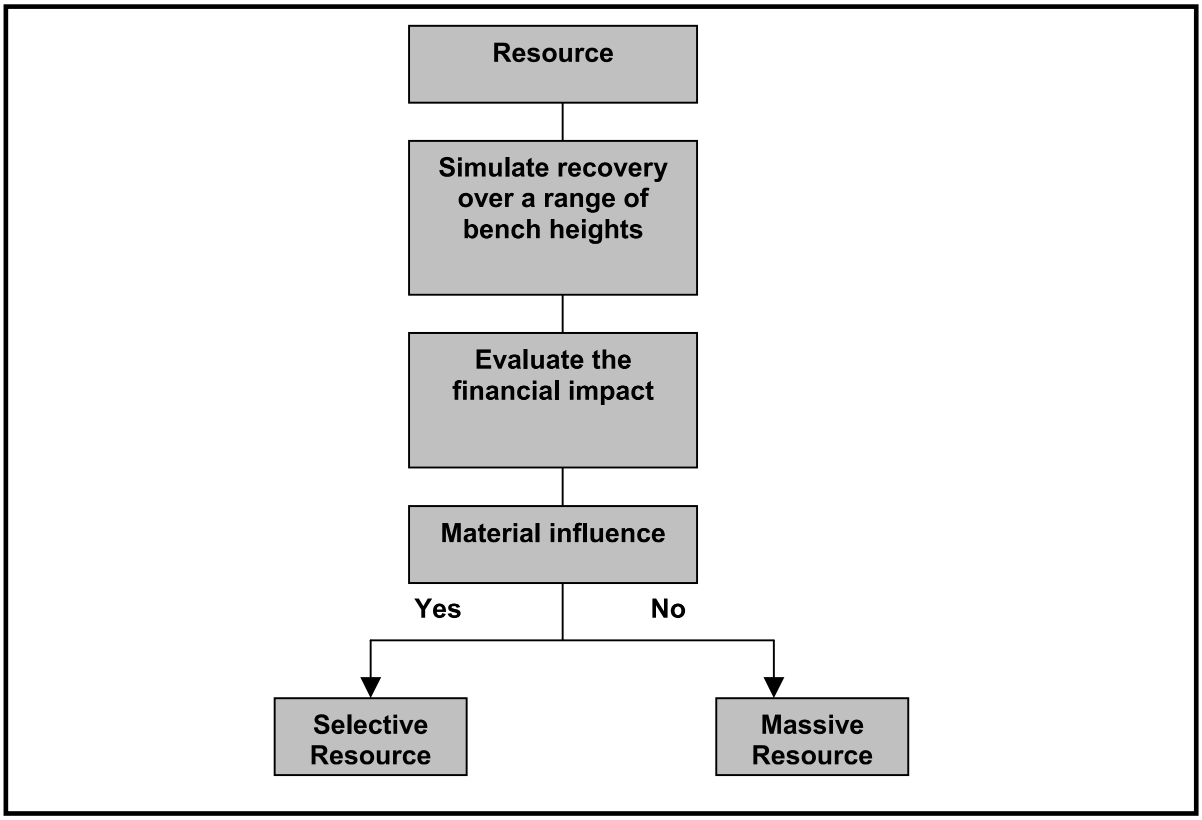


Figure 3.13 Decision flow for resource classification

How can the correct equipment selection assist in unlocking value for the mining project? What should be considered when selecting equipment in a selective resource environment? In order to answer these questions, it is necessary to gain some insight into the unique features of each shovel type. In chapter 4, a detailed discussion of the various shovel types will lay the foundation for chapter 5 where the ability of the shovel will be matched with the requirements of the ore body to deliver the combination that adds the most value to the project.

4 SHOVEL EVALUATION

4.1. Introduction

It has been determined that, although selective mining is not a new concept, little evidence exists to indicate that the full potential of the method is quantified during the equipment selection process. This finding will be tested through a review of a worldwide shovel population survey. It has also been determined in Chapter 3 that with some ore deposits, a material increase in value can be realised through a reduction in bench height and thus more effective mining recovery. However, the generic mine planning process does not provide for an ore deposit classification in terms of selectivity. It has been suggested in chapter 3 to include this step in the planning process.

But how does the planning process differ when evaluating a selective deposit? What should be considered in terms of equipment design and operating characteristics? And how are the loading requirements, determined by the ore body geometry, matched with the ability of the loading equipment? In order to answer these questions and ultimately find the perfect match, it is necessary to discuss the relevant characteristics of each shovel type.

The relevance of these characteristics is highlighted in terms of bench height and selectivity. Finally an equipment selection process is discussed, laying the foundation for economic evaluation of alternatives in chapter 5.

4.2. Shovel population worldwide

The worldwide shovel population is reviewed annually and published in the Parker Bay Report (Gilewicz, 2001). An analysis of these results over a time period will highlight trends in the population. Because the data does not allow for a separate analysis on either massive or selective ore bodies, it is accepted that any trend might to some degree be dictated by the ore body requirements. In supplying shovels to the market, the manufacturers respond to market demand, which is shaped by the selection process, and the ore bodies mined. An overview of the eventual shovel population thus gives an insight into the initial critical drivers of the selection process.

Analysing the Parker Bay report on the worldwide shovel/excavator population, it is clear that the trend towards bigger loading equipment still continues. Collectively there are nearly 3,500 large (10m^3 and larger bucket capacity) loaders operating at the 713 mines identified in this census: an average of nearly five per mine. Cumulative capacity is over 60,000 m^3 yielding an average size of 17.7m^3. (An increase of approximately 3% since the 1998 census).

With mining equipment accounting for as much as 75% of the initial capital cost of a surface mining operation, and some major equipment having a potential service life of 15 to 20 years, it is obvious that any selection of equipment will have a profound effect on the long term viability of an operation. A summary of the distribution of shovels by type and size is presented in table 4.1.

Table 4.1 Loading equipment population by product type and payload

Product Type	**No. Of Units**	**Total Capacity – m^3**	**% Of Total Capacity**
Electric	1199	26979	44%
Hydraulic	1045	16340	26%
Wheel Loaders	1243	18257	30%
Payload (cubic meters)			
< 15 m^3	1910	22821	37%
15 – 24 m^3	1045	19961	32%
25 m^3+	522	18794	31%
World Totals	**3485**	**61576**	

The distribution by shovel type, as shown in table 4.1, shows that the electric shovel still holds 44% of the total capacity worldwide. Although this represents a 10% decrease in the number of units in operation from the 1998 census, it is offset by an increase in the average shovel size to 22.5 cubic meters. The average size of shovels being delivered is far greater than the average shovel already in operation. While there are still some smaller electric shovels being sold, demand for electric shovels with dipper capacity less than 25 cubic meters has been effectively replaced by hydraulic excavators and wheel loaders as indicated in table 4.2.

Table 4.2 Loading equipment population by product type and payload, 2001 vs 1998

Product Type	**No. Of Units**	**Total Capacity – m^3**	**% Of Total Capacity**
Electric	- 10%	-4%	-4%
Hydraulic	+ 9%	+9%	-
Wheel Loaders	+20%	+20%	+4%
Payload (cubic meters)			
< 15 m^3	+13%	+12%	+2%
15 - 24 m^3	-12%	-12%	-7%
25 m^3+	+16%	+22%	+4%
Total	**+4.8%**	**+5.6%**	

The market share for hydraulic excavators appears to be leveling off in the 25% - 30% range, gaining from electric shovels in the middle of the size range and losing some ground to big new wheel loaders (refer to table 4.3).

Table 4.3 Shovel type as a percentage of the combined Hydraulic excavator and Wheel Loader.

Product Type	**1980**	**1990**	**2001**
Hydraulic	15%	30%	46%
Wheel Loaders	85%	70%	54%

It can be concluded from the report that although there are movements in the market share between the different shovel types, the momentum is generated by a drive to increase the size of the shovels. Any increase in market share is at the expense of the next bigger category of shovels and a decrease in units is offset by a further increase in capacity. This tendency might be due to an effort to reduce costs in order to utilise lower grade deposits or reserves at a higher stripping ratio. It might also be an indication of larger, massive ore deposits that are increasingly mined. There is however no evidence in the market that effective resource utilization through the correct equipment application plays a part in the evaluation criteria applied by the end user and is thus not passed on to the manufacturer to respond to.

4.3. Shovel types

Before any comparison, evaluation or selection of equipment can be made, it is necessary to look at the capabilities and limitations associated with each shovel/excavator. For the largest production rates, under tough loading conditions, the rope shovel is the most widely used loading tool. For smaller applications the wheel loader is widely used and there would scarcely be a mine that does not use one. Covering a range of loading applications, the hydraulic shovel is becoming the preferred loading tool where high productivity, selectivity and mobility are required. These comments are widely encountered and, although they are valid, it should be remembered that each site poses different challenges and limitations, which warrants a detailed investigation before any selection is made.

The purpose of equipment selection in a selective deposit is to match the ability of the loading equipment with the requirements of the ore deposit. The optimum match between equipment and ore body geometry will be achieved when the maximum selectivity can be achieved at the highest bench height. The design and operating characteristics that influence the ability to maintain selectivity at increased bench heights will be discussed in more detail. Design characteristics refer to structural design of the shovel such as the boom, dipper handle and the dipper as well as the energy source being electric or diesel powered. The operating characteristics refer to the preferred site conditions and inherent operating advantages and constraints. Not all characteristics impact on the ability to load selectively as shown in table 4.4. Only when an appreciation of each shovel type's strong and weak points is established, and the economic impact on the whole value chain is assessed, is it possible to make the right selection.

Table 4.4 Impact of design and operating characteristics on shovel selectivity

Design Characteristics		**Operating Characteristics**	
Impact on selectivity	**Yes/No**	**Impact on selectivity**	**Yes/No**
Power source	No	Loading setup	No
Boom and dipper handle	**Yes**	Production Capacity	No
Dipper	**Yes**	Digging conditions	**Yes**
Equipment mass	No	Face height	**Yes**
		Mobility	**Yes**
		Floor conditions	No
		Life of mine	No

Only the most applicable shovel types will be evaluated i.e. rope shovels, hydraulic excavators in a backhoe and face shovel configuration and wheel loaders. In order to make the evaluation comparable, the equipment sizes where selected on the basis of equivalent dipper sizes. It was found that the 15-19m^3 range was applicable to all the shovel types and was therefore selected as the most appropriate dipper size. Table 4.5 summarizes the most relevant specifications of the selected equipment.

Table 4.5 Summary of shovel/excavator specifications

Specifications	**Rope shovel**	**Wheel loader**	**Hydraulic shovel**	**Hydraulic excavator**
Manufacturer	P&H	CAT	Hitachi	Hitachi
Model	2300XPB	994D	EX2500	EX2500
Bucket capacity	19m^3	16m^3	16m^3	15m^3
Max cutting height	17.2m	8.32m	15.0m	16.16m
Bucket width	3400mm	5600mm	3800mm	3500mm

4.3.1 Rope Shovels

Rope shovels have been the mainstay for loading material in all types of mining applications since the late eighteen hundreds. There were no real changes in the machine's basic design other than it's modernization over the years. Cables replaced chains, diesel and electric motors replaced steam, and electrics and electronics were added. The rope shovel's popularity is derived, in part, from its simplicity. Figure 4.1 shows a typical rope shovel, in this case a P&H 4100, which is suited for loading, trucks in the 280 metric ton size range. The most important design characteristics of the rope shovel are the boom and dipper handle and the dipper (bucket) itself.

Figure 4.1 A P&H 4100 Electric rope shovel

a) Design Characteristics

Shovel Boom and dipper handle

The basic concept of the cable shovel is to pull a bucket up the face and slice the material into the bucket. Essentially it uses a simple front-end structure and brute force for digging as can be seen from the digging profile in figure 4.2. The boom is the structural member that supports the dipper handle and ultimately the dipper (refer to figure 4.2). The length of the boom determines the height that the dipper can be raised to and therefore the maximum bench height.

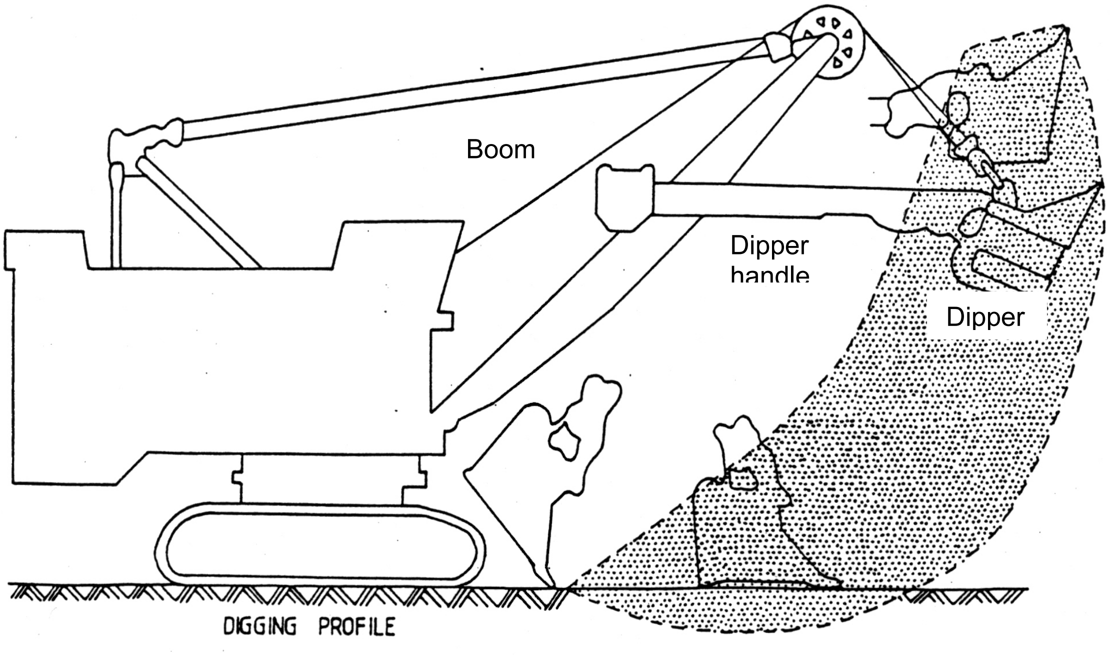


Figure 4.2 The digging profile of a rope shovel (Ford, 1986)

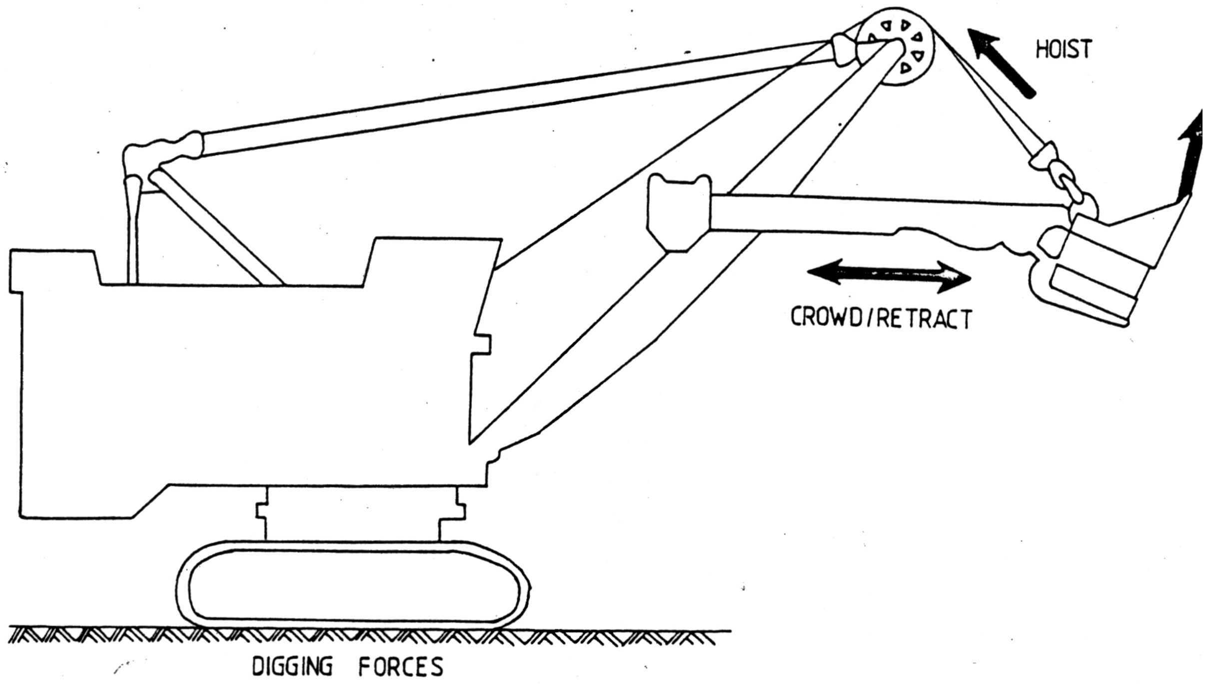


Figure 4.3 Loading forces of a rope shovel (Ford, 1986)

There are two primary forces available in the loading cycle, called the crowd force and the hoist (see figure 4.3). The crowd mechanism (the dipper handle) , can be powered in both directions, forcing the dipper into the bank during the filling phase, and withdrawing and spotting above the truck for dumping. The hoist can only power upwards and the dipper handle descends under gravity. Unfortunately the high pulling forces that the ropes are capable of carrying are not transmitted to the dipper, owing to the geometry of the linkages and the ropes themselves. A breakout force, according to the hydraulic shovel definition, is not available because the dipper is rigidly connected to the dipper handle (stick). Instead the machine uses a resultant of its hoist and crowd force, which reaches its maximum two-thirds up the face. This action requires a relative high face to ensure that the bucket is filled on its way up. This loading action imposes some constraints on the shovel;

- Since the dipper can only apply an upward force, once in the face, it has to proceed upward, causing excessive dilution.
- When starting to dig in the upper part of the face, the dipper lip has difficulties penetrating there, which also means that selective loading is not possible in that part of the face.
- Since the maximum tooth force is reached at almost maximum reach and is directed upward, the machine needs tremendous weight behind its tipping edge (axle or front idler) to avoid tipping. This explains the rope shovels heavy weight. This has an implication on the capital cost and mobility, which will be discussed later.

Shovel Dipper

The shovel dipper is the business end of the shovel and is designed for easy filling, abrasion protection whilst digging and easy emptying through the hinged rear door. Advances in dipper design and metallurgy have been substantial over the past decade, now allowing dippers with different aspect ratios. One of the biggest changes has been in the dipper width: height aspect ratio which were previously in the order of 1.2:1 and are now 1.5:1 to 1.7:1. Thus dippers are now wider and lighter. This change allows higher fill factors in smaller face heights, leading to greater range of bench heights over which rope shovels are cost effective. While a wider dipper is advantages to higher production rates, it does not improve the ability to load selectively.

Any shovel model will ultimately be sold with a dipper tailored to the operation taking into account the conditions and constraints prevailing at a specific site. A report by Paterson (2001) questions whether the dipper should be sized for the rated suspended load of the shovel, or the truck size. What he does not consider is effect of sizing the dipper to support the selective loading ability.

b) Operating Characteristics

Operating characteristics are assessed in order to determine how the digging conditions, face height and mobility influence the shovel's ability to load selectively while maintaining a high bench height.

Digging conditions

Rope shovels are suited for most digging conditions. While they are best know for high productivity in difficult, hard conditions, they also perform well in softer conditions where faces are reasonably stable. These conditions favor selective loading because little disturbance of the material occurs before loading proceeds. Free flowing material is not well suited to rope shovels because of the difficulty of clean up.

Face height

Because of the raking action it is difficult to fill the dipper in one pass if there is insufficient face height. As a rule of thumb, the design bench height should be equal to the height above the floor of the boom point sheave. This should be reduced by 10% - 20% if the material is not well blasted. The minimum face height depends on the type of material but should generally be such that the digging cycle should not exceed 15 seconds. Based on the geometry of a PH 2300 shovel and numerous field tests the minimum and maximum productive face heights can be set at between 8m and 17m. It is however possible to reduce the face height to an ultimate minimum of 4m which is equal to the dipper height. This will have an adverse influence on the productivity. These limits influence the ability to load selectively because the lower bench heights cannot practically_be considered.

Mobility

Rope shovels have limited mobility due to the large weight of the machine as well as the restriction of the electric cable. It would be reasonable to state that the maximum distance that a rope shovel should be trammed for one shift's production should not exceed 500m (up and back). While this does not affect the selective loading ability, it does impose limits on the ability to blend different material types, which are often required when selectivity is required. It also reduces the efficiency on lower bench heights because of the more rapid lateral advance required on the lower benches.

4.3.2 Hydraulic Shovels/Excavator

Due to the successful application of hydraulics on backhoes and front-end loaders in construction projects, the principle was transferred, mainly in Europe, to small capacity shovels in the early 1950's. Since its introduction, the hydraulic excavator has undergone an amazing development in various respects. On the technical side the very basic machine has evolved into a sophisticated, fully hydraulic excavator and on the application side, it is difficult to imagine a loading condition that could not be handled by the hydraulic shovel or excavator.

The hydraulic shovel/excavator was developed, in part, to compensate for the shortcomings of the rope shovel. Consequently the one major advantage over the rope shovel is that, with careful design, the forces generated by the hydraulic cylinders can be applied with maximum effect. The hydraulic shovel/excavator uses very effective crowd and breakout forces and to a lesser extent, a lifting action to perform the digging action. This implies that the digging action is not one of raking up the face but of crowding in and excavating the face from the top down or bottom up. The success of the hydraulic shovel / excavator lays in the versatility and adaptability to different tasks.

The basic concept of the hydraulic shovel/excavator consists of the undercarriage, upper carriage and the attachment that consists of a boom, stick and shovel bucket as shown in figure 4.4. To increase the effective application of the hydraulic shovel, the boom and stick configuration can be changed to differentiate between a face shovel and a backhoe excavator. The backhoe version is primarily designed to excavate below level and the shovel version to load on or above the excavator level. Each type will be discussed individually.

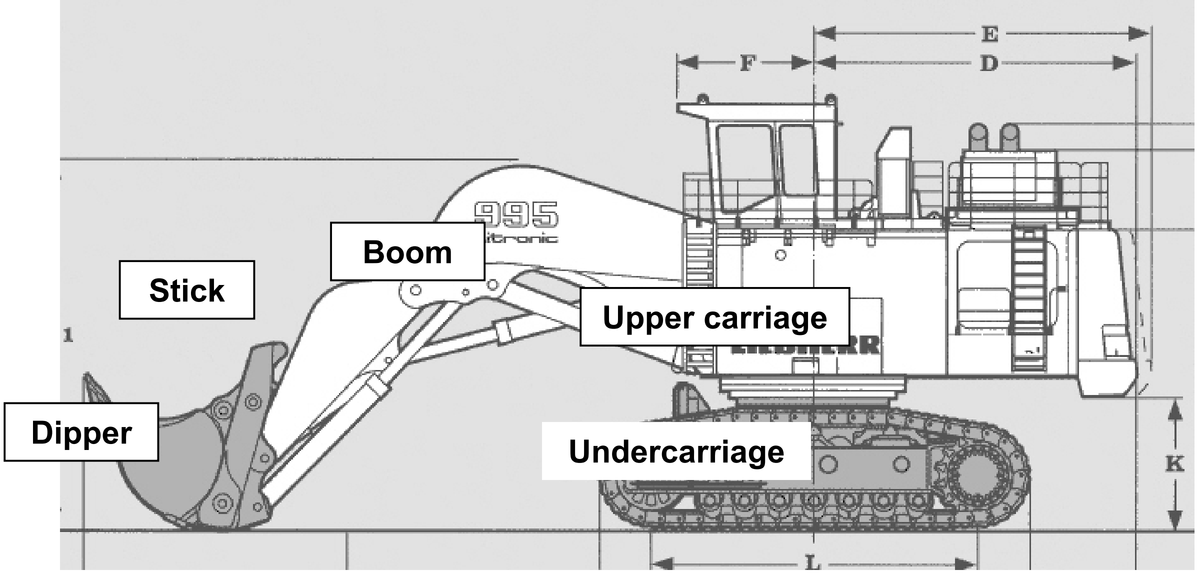


Figure 4.4 A typical hydraulic face shovel configuration (Liebherr)

Face Shovel Configuration

a) Design Characteristics

Shovel Boom and dipper handle (Stick)

The undercarriage and upper structure forms the basic machine that can be equipped with either a backhoe or a front shovel attachment. The hydraulic excavator supports the bucket on two pivoted arms, called the boom and the stick. Two lift cylinders support the boom and two crowd cylinders attached to the boom support the stick. The bucket is controlled by two bucket-cylinders. The two attachments are necessary to provide the crowd force into the bank.

The hydraulic shovel uses three separate forces in the excavating cycle called the crowd, breakout and the lift as indicated in figure 4.5. The normal method to fill the bucket will be to penetrate the material with the crowd force and then break it out by curling the bucket applying the breakout force. The stick or crowd cylinders generate the crowd force at the tooth tips. It can be directed down, parallel to the floor, or upward anywhere in the attachment's range to match material strata or follow the path of least resistance for fast and complete bucket fill. The higher up in the face the crowd force is applied, the more its reaction force will add to the machines pushing itself into the floor and keep it from being pushed backwards.

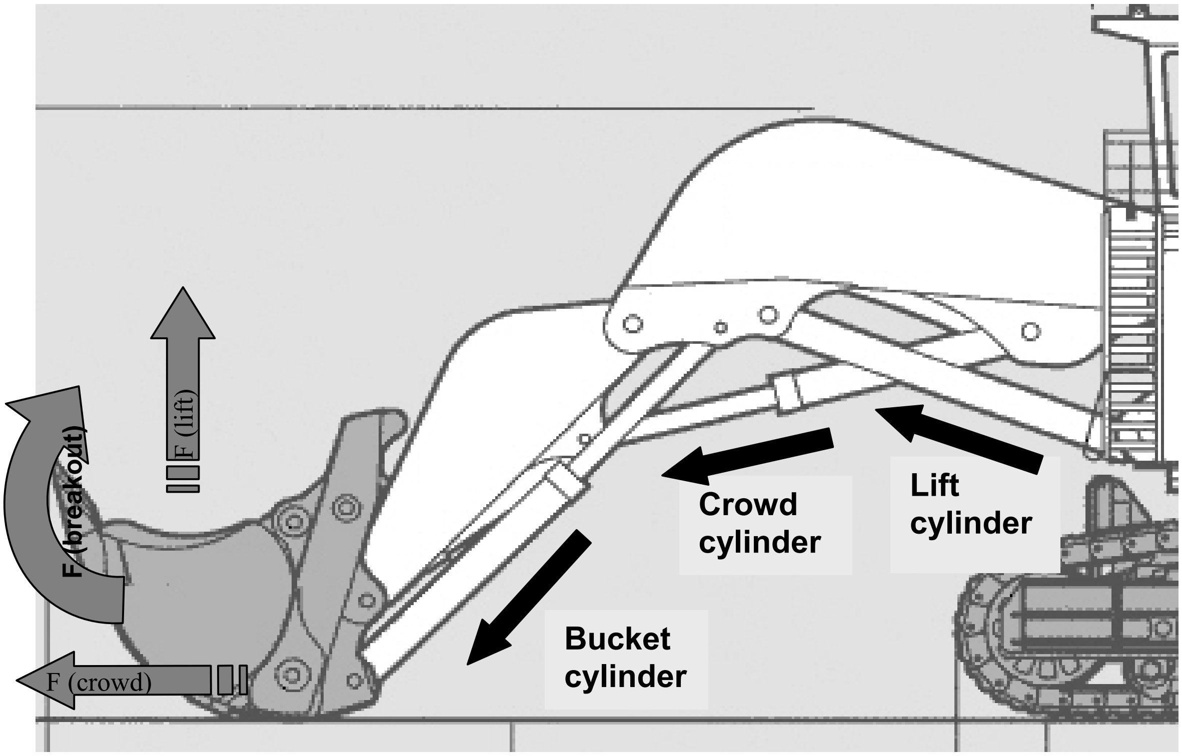


Figure 4.5 Excavating forces (Liebherr)

Once the crowd force has pushed the bucket into the material and penetration stops because of resistance, the independent bucket breakout action loosens the material and fills the bucket. This breakout force stems from the bucket cylinder force pushing down on the bucket and rotating it around its pivot at stick end. Through careful design the required breakout force is available from the start of the loading cycle and is retained over a relative large range. This ensures that the bucket is filled relatively quickly and results in a high production rate. The fact that the crowd force can be applied at almost any height in the working face is the key to the machine's ability to excavate selectively.

The lifting force applied by the lift cylinders is not as effective as the crowd and breakout forces. It is clear from the discussion that the lifting action is not used to fill the bucket, but rather to position the bucket in the working face.

Shovel Dipper

With the face shovel the bucket geometry is a careful balance of width, depth and height. Buckets that are too wide can cause instability, and asymmetrical forces during loading should be avoided. For the same capacity, narrower buckets have to be deeper or higher – in both cases resulting in either the required loading height increasing to ensure proper dumping, and/or less control on the forces at the cutting edge.

Compared to the front dump bucket of the wheel loader, this bucket has considerable advantages, the biggest being an increased dumping height. This realizes due to the fact that the front of the bucket is controlled hydraulically and lifts upwards. This implies that larger trucks can be utilized on long hauling distances.

b) Operating Characteristics

Digging conditions

Hydraulic face shovels are suited for most digging conditions. Several types of excavation faces can be excavated as shown in figure 4.6. Because of the effective application of loading forces, the hydraulic shovel can load consolidated or poorly blasted faces. The high break out force is often applied to perform "free digging", which requires no drilling and blasting. These conditions support selective loading over a range of bench heights, i.e. selectivity of 3m can be maintained while mining a 12m bench height. However, this is only possible if the face angle of the blasted material allows the shovel to get close enough to the face to fill the bucket. If this is not the case, the shovel has to load from the toe area, causing total dilution and eliminating the possibility of selective loading.

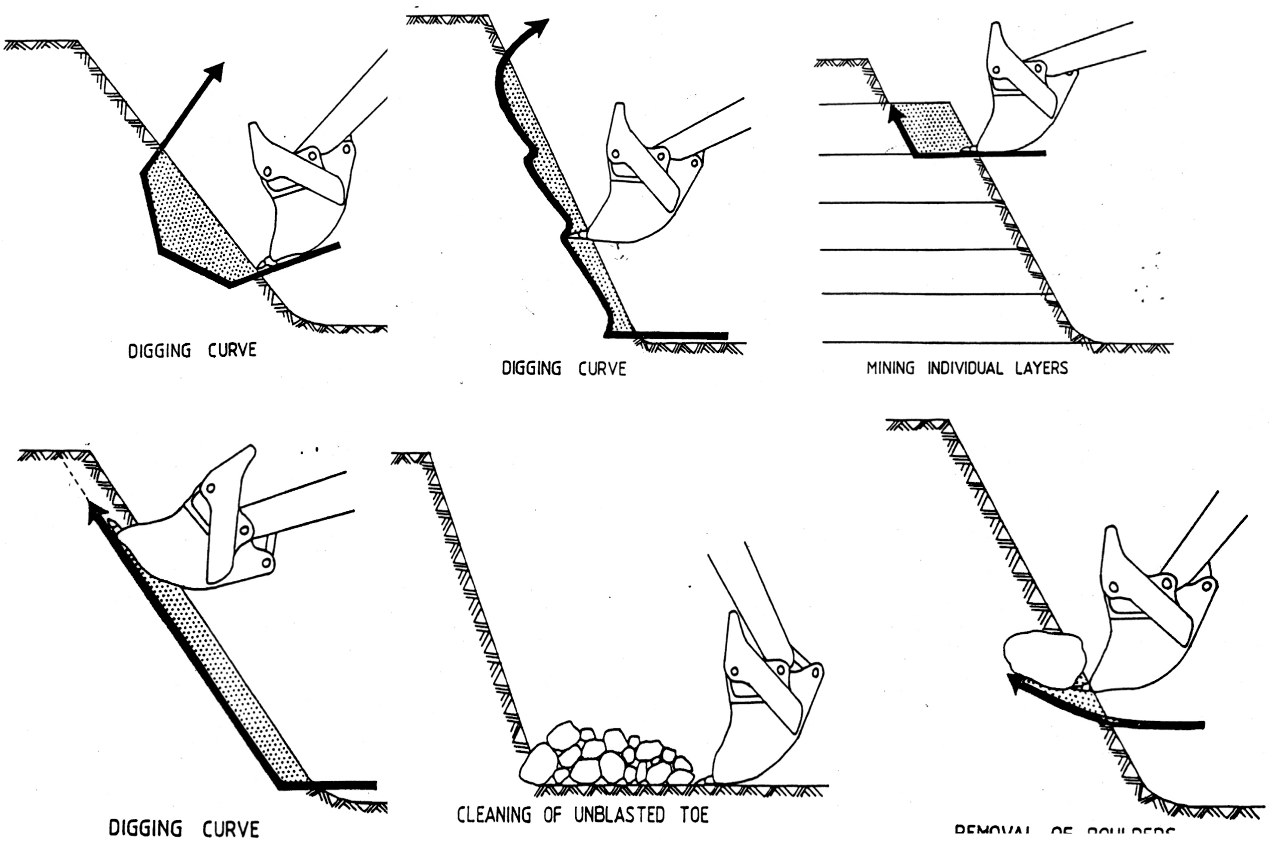


Figure 4.6 Types of excavation faces (Ford, 1986)

Face height

The hydraulic shovel can operate efficiently in any face height up to typically 15m. Although the type of material e.g. free flowing, consolidated ect. determines the effective bench height, it is important to know that the bench height is not as critical to the hydraulic shovel as it is to the rope shovel. The reason is the different loading action. The hydraulic shovel is an intelligent loading tool, applying crowd, breakout and hoist actions to fill the bucket and does not rely on a raking action over the full height of the face. The specification provided by Liebherr for a R994 Face Shovel (16m^3) indicate that 80% productivity can be obtained with a bench height ranging between 4.5m and 12m. (Domaschenz 2001)

Mobility

When assessing mobility of a shovel, it is necessary to distinguish between crawler mounted and rubber wheeled units. Rubber wheeled units such as wheel loaders are extremely mobile. All hydraulic shovels are crawler mounted. They do however have increased mobility compared to the rope shovel due to the lower weight and increased drawbar pull. The high drawbar pull allows the machine to negotiate slopes of up to 45° and enables the machine to extract itself, even if the tracks are partially covered in soft or clayey floors. Mobility is also important when ore blending requires material from different faces during a shift. This is practical within a range of a few hundred meters, preferably on the same bench. Lower bench heights will imply higher lateral face advances, causing more frequent repositioning, which requires mobility.

Backhoe configuration

For any given undercarriage and upperstructure, it is possible to convert the hydraulic excavator, without very much effort, from backhoe to face shovel attachment and vice versa. The biggest difference is in the boom and stick configuration which impacts on the dipper size, loading setup, production capacity and face height. Figure 4.7 shows a typical backhoe configuration.

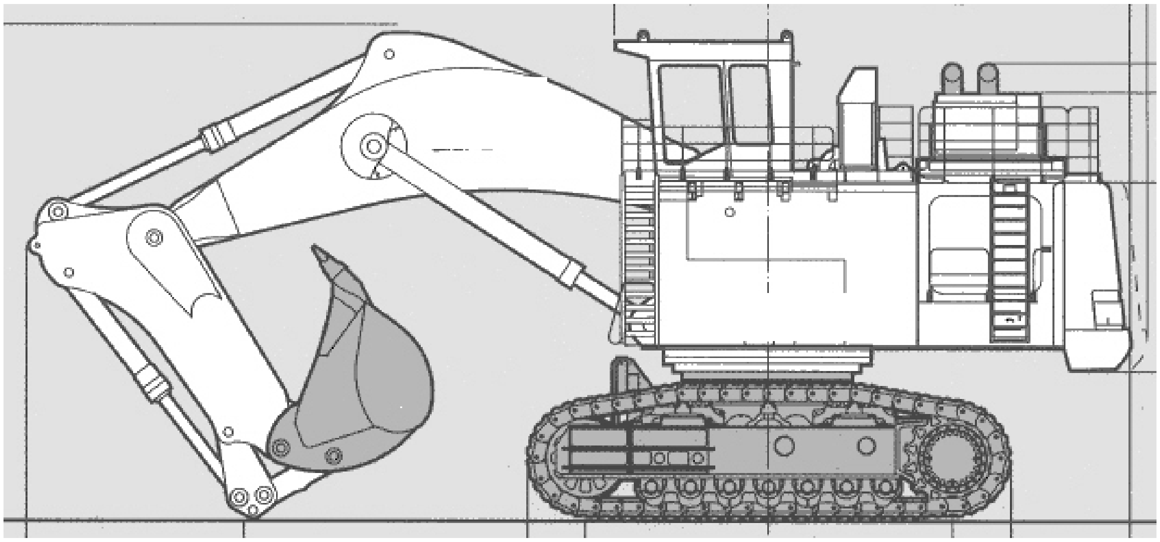


Figure 4.7 Backhoe configuration (Liebherr)

a) Design Characteristics

Shovel Boom and dipper handle (Stick)

The significant difference between the face shovel and the backhoe is in the boom and stick configuration. This implies that they differ in their digging action and cut profiles. In the backhoe configuration, the boom is usually longer allowing a greater reach – but also a smaller bucket. As with the face shovel, hydraulic forces on the backhoe are set up for efficient crowd and breakout, but less efficient in pure lift.

Shovel Dipper

For backhoes, bucket geometry is much different than for the face shovel configuration. Buckets are narrower and deeper which are easier to control. For the same size hydraulic excavator, the bucket on the backhoe configuration is generally smaller than the bucket on the front shovel configuration. This is because of the longer reach and also because backhoe buckets typically achieve higher fill factors. Basically backhoes trade bucket size for reach. The smaller buckets also increase the selective loading ability. Table 4.6 compares typical bucket sizes for the same size of excavator in different configurations (Maehlmann, 1988).

Table 4.6 Comparison of bucket sizes for shovel and excavator configurations

Service weight (tons)	55	70	90	120	200	280
Approx. standard bucket size (m^3) for specific weight up to 1.8 t/m^3						
Shovel version	3.4	4.3	6.0	8.1	12.0	15.0
Backhoe version	3.25	4.0	5.5	7.3	11.5	14.0

Wiebmer (1993*)* reports that actual field tests proofed that the bucket-fill factor for a backhoe configuration could typically be 100%. The bucket design can be matched to any type of material, thereby ensuring the right bucket for the right task. The narrow bucket and short tip radius enables the excavator to develop large digging and breakout forces. While the smaller bucket do not support a higher production capacity it does significantly increase the ability to load selectively.

b) Operating Characteristics

Digging conditions

Hydraulic excavators are suited too most digging conditions. Banded seam horizons are a good application for hydraulic backhoes because of the ease with which they can selectively dig between the bands. The ability to work the face from the top down enables it to perform in digging conditions that may not be possible to work in any other way. However, in applications where unblasted or poorly blasted rock has to be mined, the backhoe machine has a disadvantage compared to the shovel. For one the shovel operator will in most cases have a better view of the face, which will enable him to spot a crack in the material where he can attack with the high breakout force. Massive boulders are easier to see from the shovel operator's cab. The backhoe can perform well in tight digging conditions where space is limited and the bench height is suited to the stick length.

Face height

Because the backhoe is positioned on the upper bench, the bench height should not be larger than the stick length. If the bench height exceeds the stick length, typically 5-6m, the machine will have difficulties in producing at its optimum. Whereas the face shovel or rope shovel will improve the fill factor of the bucket with increased bench height, the backhoe will find it more and more difficult to reach the bottom of the bench in order to keep the truck loading area clean. Since the stick length and bucket size are negatively correlated, an increased stick length will reduce the bucket size to a point where economical production cannot be maintained. The higher bench height can be addressed by excavating the face in multiple phases, but this might cause severe dilution and reduce the success of selective loading.

4.3.3 Wheel Loaders

Wheel loaders or Front End Loaders (FEL's) first appeared in the 1940's, long before hydraulic shovels. Those machines with front end resembling that of a rope shovel were crawler mounted, but with the advances in tyre and hydraulic technology, the machines evolved into the compact and mobile versions that exists today. In the early years it had a rigid frame and axle pivot steering, but the mid 1960's saw the development of the wheel loader with center pivot steering and rigid mounted axles. Only with this kind of axle did it become possible to build wheel loaders with high payload capacities such as the unit shown in figure 4.8.

The wheel loader was developed as a loading tool, not an excavating tool, to handle loose and stockpiled material. But with successive generations, its design has grown aggressive enough to tackle well-blasted production faces. The basic design characteristics of the wheel loader consist of the front-end boom arrangement and the bucket.

Figure 4.8 CAT 994 Wheel loader

a) Design Characteristics

Front-end Boom Arrangement

Front-end loaders generally support the bucket on a one-piece arm pivoted on the front of the loader. The arm is raised or lowered by hydraulic arms, and the tilt of the bucket is controlled by a second set of hydraulics and link mechanisms, also ultimately supported on the front of the loader. Two alternative front-end arrangements are commonly offered - a standard arrangement and a high-lift arrangement. High lift arrangements are equipped with smaller buckets but permit easier loading of larger trucks.

The machine digs by filling its bucket with a combination of crowding action produced by traction, a limited breakout force produced by a twisting action and a lifting force through a hoisting movement as shown in figure 4.9. The loading profile of the wheel loader is shown in figure 4.10. The reason for starting the loading action at floor level is twofold. In order to protect the tyres it is necessary to clean the floor while moving into the face. Secondly, sufficient crowd force can only be applied at floor level. This implies that the bucket is filled from the bottom of the face, similar to the rope shovel, reducing the opportunity for selective loading.

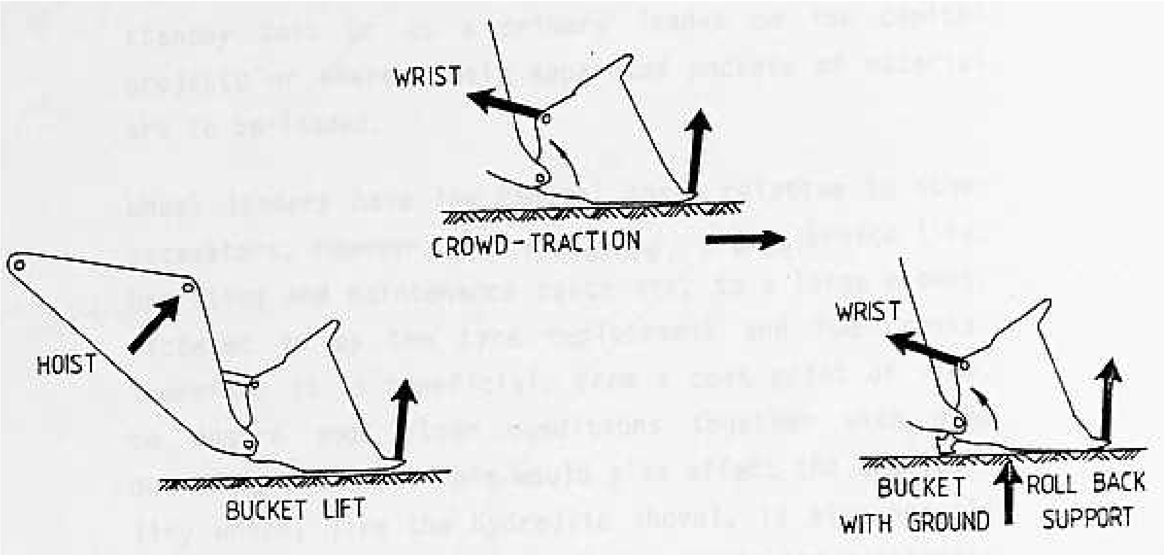


Figure 4.9 Loading forces (Ford, 1986)

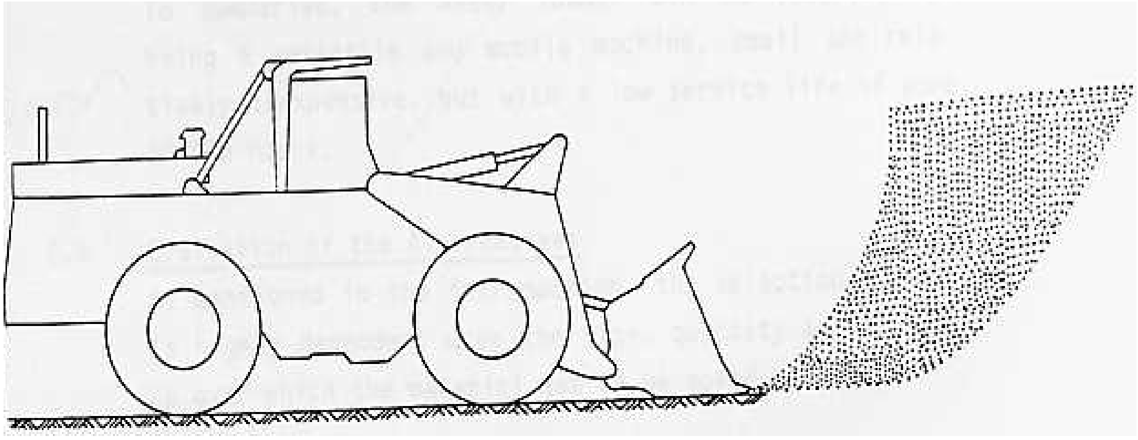


Figure 4.10 Loading action (Ford, 1986)

The wheel loader differs from the rope shovel and hydraulic shovel in that the loading action is not carried out from a stand still. Because of the fact that the crowding action is applied by propelling the machine into the material, the traction, floor conditions and machine mass all influence the practical crowd or penetration force that can be applied at the start of the loading cycle. Penetration is generally poor because of the low linear pressure on the edge of the bucket brought about by the very wide buckets that are used in order to protect the front tyres. The traction effort that the loader can develop has been improved by means of various systems of limited-slip-differentials to overcome unfavorable ground conditions. With conventional differential the wheel may spin, in which case the drawbar pull becomes zero.

Shovel Bucket

Bucket selection will play an integral part in the efficiency of the wheel loader and is influenced by the material type and truck to be loaded, production rates required, cost ext. Bucket loadability is a function of width, height, depth, curvature, material thickness, cutting edge shape (straight versus V-type) and ground engagement tools (GET) options. The optimum combination of these attributes allows a bucket to penetrate the material, fill the bucket and dump the material. The ability to penetrate the material is determined by the cutting edge thickness, shape and width. A thin edge penetrates better, but does not wear as well as a thicker edge and a V-type edge penetrates better than a straight edge. The bucket width is determined by the tyre coverage required as well as the dump target.

The ease of material flow in and out of a bucket depends on the depth, height and curvature of the bucket. Different material requires different height-to-depth-to-width-to-curvature relationships. Material that is easy to penetrate will allow a wider and deeper bucket. Material that is difficult to penetrate requires a narrow, shallower bucket. This bucket penetrates less surface area and has more breakout force. Sticky material will require a more open curvature and a shallow bucket.

It is clear that the selection of a bucket is influenced by many factors, other than selectivity. It is for this reason that the bucket seldom enhances the selective mining ability of the wheel loader.

b) Operating Characteristics

Digging conditions

Front-end loaders are best suited to free flowing or well-blasted material and are not usually considered for hard digging conditions. The application of the different loading forces is limited which limits the application of the loader in difficult faces. This implies that considerable dilution is caused by the rock breaking action, which is increased during the flowing of the material. The conditions do not support selective mining at all.

Face height

A wheel loader generates the biggest crowd force when the bucket is at floor level. This implies that the lowest effective bench height is equal to the bucket height. The maximum bench height should not exceed the hinge pin height at full lift. Exceeding this height in a competent face will lead to undermining of the face and will create dangerous loading conditions. Wheel loaders can operate efficiently on any face height up to 10m if the fragmentation is good and the material is free flowing. This is seldom the case in mining operations and therefore front-end loaders are normally used in lower bench heights. The advantage of using a front-end loader on these lower benches is that the mobility suites the high lateral advancing rate of the face. A rule of thumb states that an effective bench height does not exceed the hinge pin height at full lift. For a CAT 994D this results in an efficient bench height ranging from 4m to 8.30m. Although the wheel loader can benefit from low bench heights in terms of selectivity, it cannot simultaneously benefit in terms of production cost from higher bench heights.

Mobility

A wheel loader is designed to carry 18-21% of its operating weight as a bucket payload and thus have a very favorable payload-to-operating weight ratio, which translates into very high mobility. The articulated frame and rubber tyre mountings result in excellent maneuverability and mobility. Unfortunately the machines mobility also results in one of its most serious drawbacks, namely the need to propel the machine during the loading cycle. The high mobility of the wheel loader is its most competitive advantage in a mining application because it can be used for loading multiple faces during one shift for blending reasons and as a back up to other shovels. The high degree of mobility has two major drawbacks. The larger number of modes of movement requires greater operator skill and concentration and the wheel loader is often used for secondary applications, reducing its total production output.

4.4. Selectivity and bench height

It is clear from the discussion that each shovel has unique features in which it excels above the competition. It is a matter of matching the key value driver in the specific mining process with the right excavating tool. A rope shovel is renowned for its robustness and high production rates, the wheel loader for excellent mobility and the hydraulic shovel for selectivity. Production rates and mobility can be quantified and measured and it is thus easy to evaluate and compare different excavating tools in terms of these features. But what is selectivity really about, how is it measured and how does the end-user compare different options?

Selectivity or selective mining can be described as the ability to distinguish between ore and waste during the loading or excavating cycle. It is an action performed to minimize dilution and maximize ore recovery. In fact, conditions permitting, it can be seen as the first step of beneficiation applied in the loading face. The advantage gained from selective mining is site specific. When ore is hauled over a long distance it is important to reduce the amount of waste on the haul truck, as this is an unnecessary expense. Depending on the type of beneficiation, substantial savings can be realized if the process is adjusted to take advantage of less dilution in the plant feed. If this is incorporated into the project planning the savings can be even bigger during the design phase of the plant.

The extent to which selective mining can be applied is influenced by various factors, the most significant one being the geometry and geological complexity of the ore body. Not all ore bodies justify the additional effort and expense to increase the recovery and/or reduce dilution. However if an ore body is classified as a selective deposit as discussed in Chapter 3, the potential for a substantial increase in value exists and further investigation is warranted.

The pit geometry also contributes to the success of the selective mining effort. The bench height and the mining direction are of utmost importance. This implies that sufficient pit room should be available to enable the scheduler to change the direction of attack, should it be required by the geometry of the ore body.

The selection of the optimum bench height is achieved by matching the requirements of the ore body and the ability of the excavating equipment. The grade tonnage curve results indicate the recovery at various bench heights for optimum recovery, assuming vertical blending during the loading action. It is then up to the equipment selection engineer to interpret the ability of equipment and determine the most economical bench height at which the required recovery can still be achieved. The selective ability of the equipment is determined through an assessment of the various factors discussed previously.

It stems from this discussion that it is not possible to apply a generic evaluation to equipment in terms of its selectivity. Far more effective would be an equipment selection process as indicated in figure 4.11. This process should be followed when the ore deposit is classified as being a selective deposit. If the deposit is classified as a massive deposit, the traditional evaluation in terms of the lowest production cost should be used. Thorough knowledge of each equipment type will be necessary to evaluate the equipment in each situation.

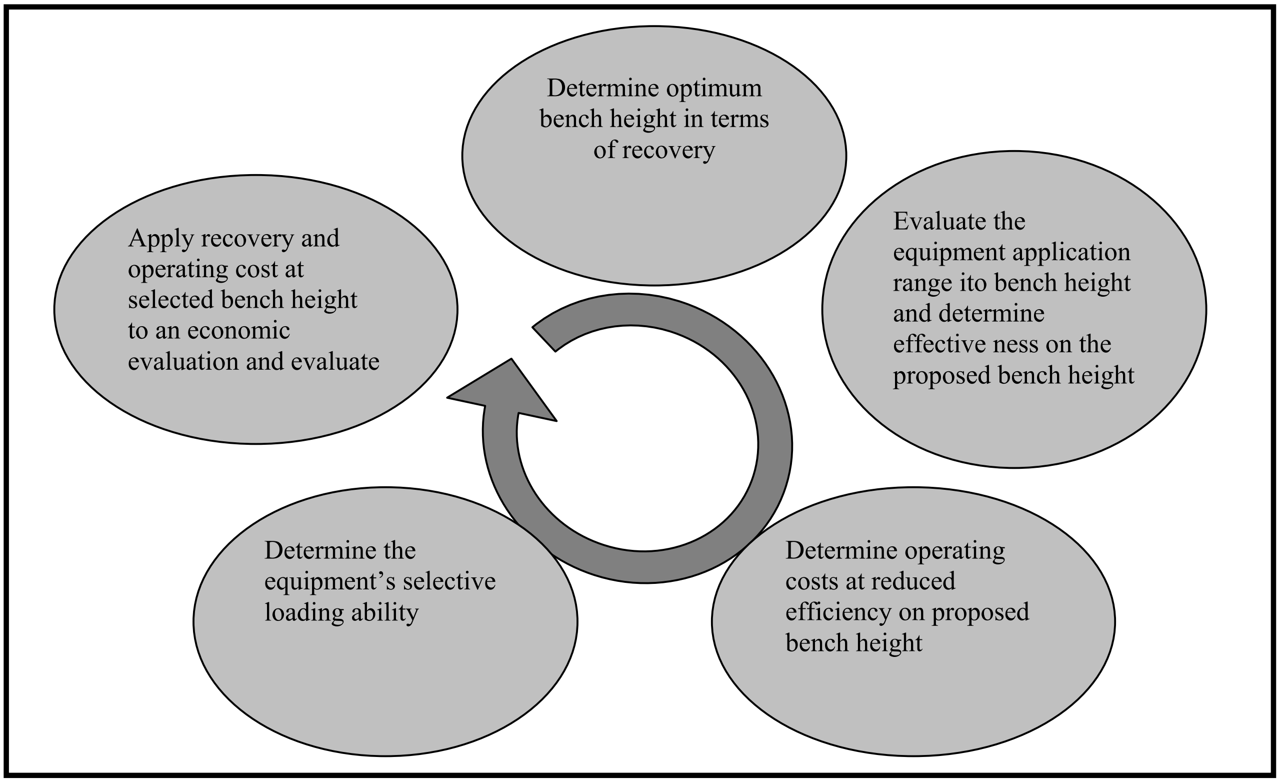


Figure 4.11 Equipment selection process, taking selectivity into account

The use of grade tonnage curves will indicate whether potential exists to increase recovery through selective mining. It has been established in chapter 3 that significant potential does exist for the Thabazimbi ore deposits. It remains to be determined which shovel type can take advantage of the increased recover at the lowest operating cost penalty.

The proposed process of shovel evaluation will be demonstrated through the use of an example. The equipment indicated in table 4.5 will be assessed in relation to the design and operating characteristics in terms of selectivity at various bench heights. The results will be used in an economic evaluation in chapter 5.

4.4.1 Equipment effective application range in terms of bench height

It has been shown earlier that most loading equipment can be utilized over a wide range of bench heights, however not with the same efficiency. The maximum and minimum bench heights are physical limits wherein the equipment can operate efficiently and safely. The bigger the difference between the two limits, the better the adaptability in various conditions and the safer the equipment decision over a long period. Figure 4.12 gives a graphical representation of the possible bench heights for the various shovel types under discussion. The hatched section on the hydraulic and wheel loader bars indicate that loading is still physically possible, although all selectivity is lost. This is due to the prerequisite that the material must be free flowing in the case of the wheel loader and that the excavator will be performing mid bench loading to negotiate the higher bench heights.

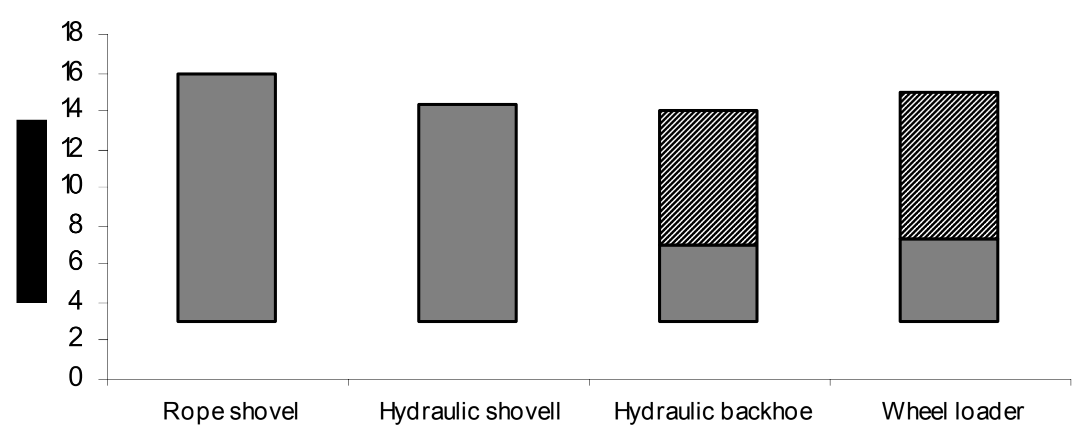


Figure 4.12 Productive bench height limitations

Figure 4.13 indicates the productivity of these different shovels at various bench heights. These figures were obtained with simulations done on TALPAC, which is a software system that is used for determining the productivity and economics of truck and loader haulage systems (Runge Mining). Information is supplied in terms of material type, haul truck selection, working roster, haul segments and shovel selection. Inputs include bucket size, fill factors, cycle time and loading setup. The bucket fill factors and cycle times were adjusted in order to simulate the production rate at various bench heights. Assumptions were made in terms of the hauling distance (4km return), material density (3,2 t/m^3) and loading setup (double sided). Refer to appendix C for full simulation results.

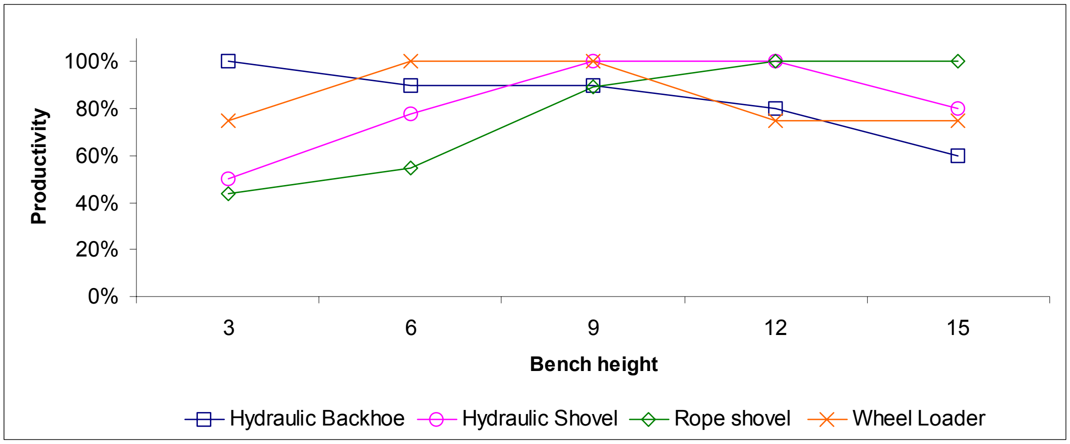


Figure 4.13 Simulation results of productivity at various bench heights

4.4.2 Equipment selective mining abilities

The selected shovels will be evaluated in terms of dipper configuration, loading action and digging conditions or fragmentation.

Dipper configuration:

In order to improve selectivity the dipper size must be of such dimensions that material can be “picked” from the face during the loading action. The selective ability will be improved if the face area of the dipper is reduced. This means a decrease in the height or width of the bucket. To compare the dipper configurations in terms of selectivity, a ratio can be calculated where the face area is related to the dipper volume. The higher the ratio, the better suited to selective loading. Table 4.7 summarizes the dimensions for each of the different shovel types, from which it can be seen that the wheel loader is least suitable for selective loading.

Table 4.7 Selective loading ability expressed in a face area ratio

	Capacity	**Width**	**Height**	**Ratio** m^3**/ face area**
Rope Shovel	19 m^3	3400mm	3500mm	1.60
Hydraulic shovel	16 m^3	3800mm	3500mm	1.20
Hydraulic Backhoe	15 m^3	3500mm	3400mm	1.26
Wheel Loader	16 m^3	5600mm	2500mm	1.14

Loading action:

This is one of the most important features determining the selective loading ability of the equipment. It is a measure of the ability to divide the face into smaller effective bench heights during loading. The equipment can distinguish vertically between different material types while maintaining a bench height higher than the segment being loaded. Based on the detail discussions of each shovel type the following comments can be made in terms of the loading action, as given in Table 4.8.

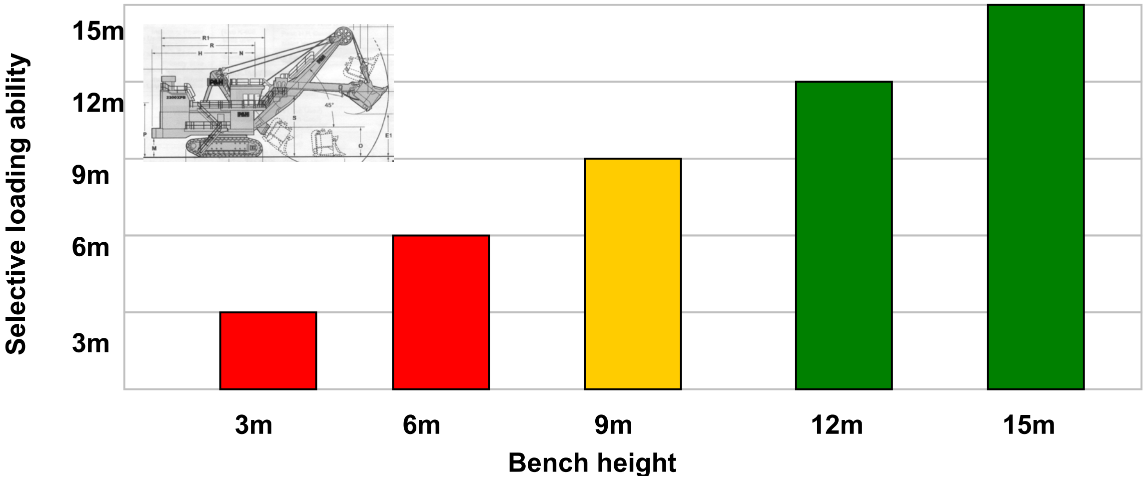
Table 4.8 Loading action and selectivity

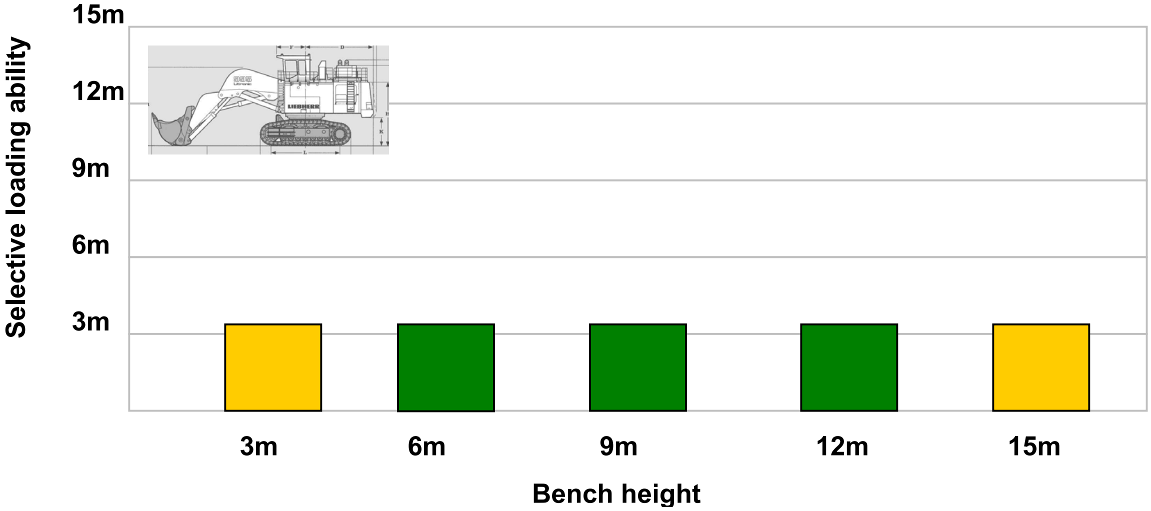
Shovel type	Comment
Rope shovel	This shovel cannot distinguish between different material types during the loading cycle. The selective ability is equal to the selected bench height.
Hydraulic Face shovel	This shovel can distinguish between different material types during the loading cycle. In a competent face the selectivity is limited to the bucket height and is not influenced by the bench height as long as it stays within the maximum limits.
Hydraulic Excavator	This shovel can distinguish different material types during the loading cycle. The selectivity is limited to the bucket size as long as the face can be excavated in one cut. As soon as the bench has to be divided, contamination will occur. The selective ability will then be assumed equal to the bench height for the purpose of the evaluation.
Wheel loader	This loader's selectivity is limited to its bucket height. This only applies to a bench height not exceeding the hinge pin height. As soon as the hinge pin height is exceeded, free flowing material is required and all selectivity is lost.

Fragmentation:

When discussing digability of material, a distinction can be made between material that can be dug freely and material that has to be blasted. The degree to which the material is broken during blasting is referred to as fragmentation. Fragmentation can be described as the size distribution of the material being loaded and can range from very fine, free flowing material to what is referred to as *crack* blasting where the material stays intact but is broken to the degree that excavating can take place. The required fragmentation can have a profound influence on the opportunity to do selective loading. The higher the required fragmentation, the more disturbance and thus dilution will occur on the ore waste contacts. The required fragmentation for effective loading is determined by the loading action of the equipment, the available forces and the way in which the forces are applied. The hydraulic shovel can handle poorer fragmentation due to the intelligent application of the different digging forces while the wheel loader is dependant on very good fragmentation. The rope shovel can also handle very tough digging conditions.

It is evident from the preceding discussion on bench height limits and selective ability that the ability to load selectively cannot be calculated. It is rather a judgment made on a thorough evaluation of the design and operating features of each shovel type in conjunction with the ore body geometric parameters. The anticipated selective digging ability at various bench heights for each shovel type in the Thabazimbi scenario is indicated in figure 4.14.





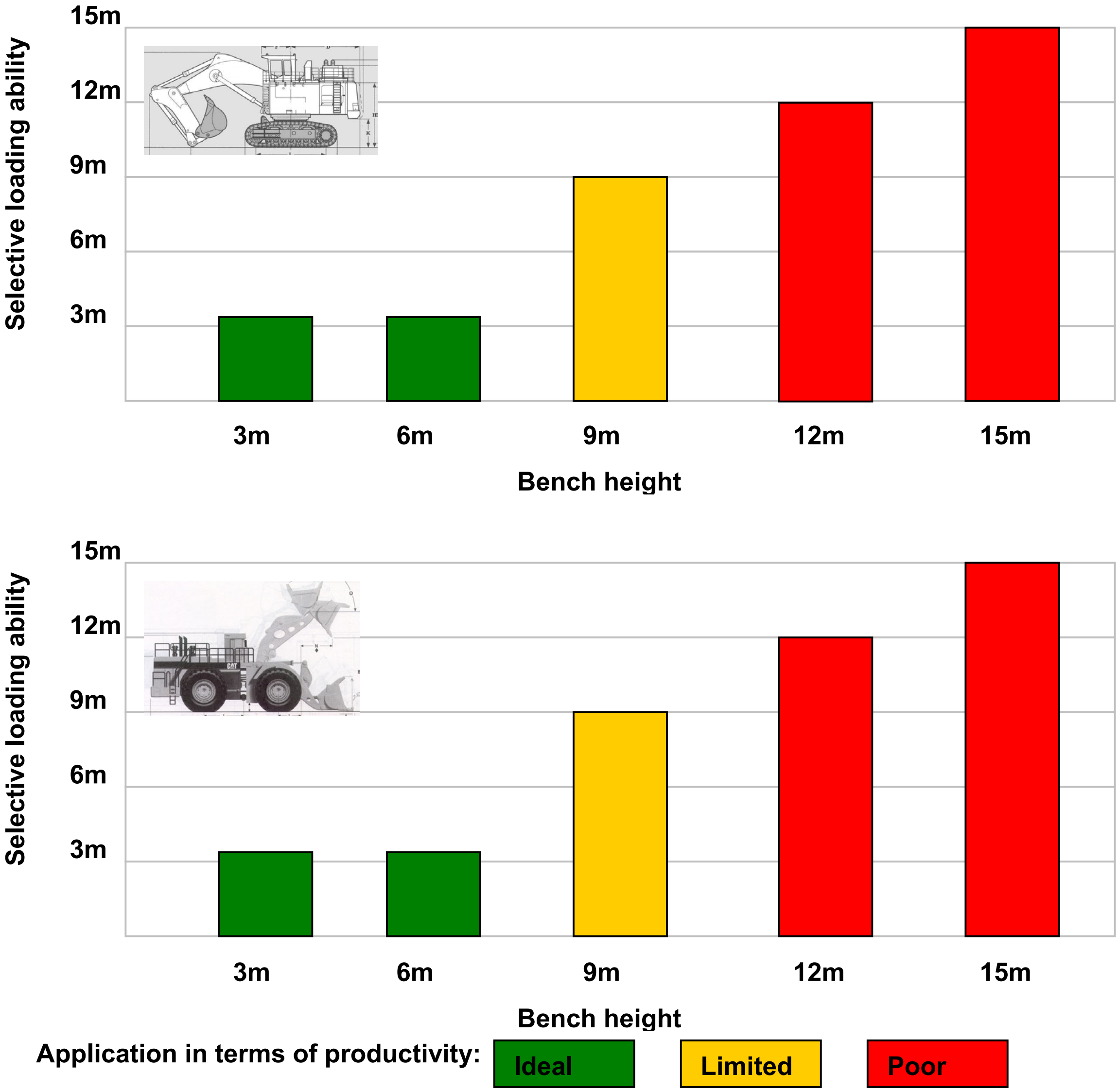


Figure 4.14 Graphical presentation of bench height and selective loading ability

The selective ability at various bench heights has now been estimated. It is now possible to economically evaluate each scenario to determine which option will yield the highest return on investment. This will be addressed in chapter 5.

5 ECONOMIC EVALUATION

5.1. Introduction

This chapter provides a detailed discussion of the economic evaluation of the various alternatives proposed in figure 5.1. The purpose of the evaluation is to determine the combination of bench height and shovel selection that creates the most value through increased ore recovery. Each alternative has been incorporated into a cash flow model for the calculation of the economic results.

5.2. Economic Evaluation

5.2.1 Evaluation Approach, Techniques and Assumptions

The scenarios were evaluated using the discounted cash flow technique, where capital and operating costs of each scenario were discounted against the projected revenue from iron ore sales to the market.

Project profitability was calculated in terms of an internal rate of return (IRR) and net present value (NPV). In order to take cognisance of the expected cost/revenue escalation differential, the evaluation was done in nominal terms using the cost/revenue escalation rates as shown in appendix D. The hurdle rate (cost of capital) was taken at 12% after escalation and tax (in real terms).

The program used for the evaluation was developed by Kumba Resources and is used for project evaluation by the company. The evaluation process is shown schematically in Table 5.1. The program has the ability to do multiple evaluations on various macro economic indicators but since the purpose of the evaluation is to compare alternative production scenarios and not the actual feasibility of the project, these facilities where not used. An example of the complete evaluation for the rope shovel is included in appendix E.

Table 5.1 Economic evaluation process

	Evaluation
1	Production Schedule
2	Net sales
3	Cost of sales Variable Fixed
4	EBIT*
5	Capex schedule
6	Tax
7	NPV IRR

* Earnings before interest and tax

Alternatives selected for evaluation

Various alternatives have been identified for evaluation. It consists of a combination of each shovel type at a bench height varying from 3m to 15m in 3-meter intervals as indicated graphically in figure 5.1. Although all the alternatives might not be economically justifiable, it is physically possible if the correct conditions prevail, e.g. free flowing material for the wheel loader and mid bench loading for the excavator. A financial analysis was done for each alternative.

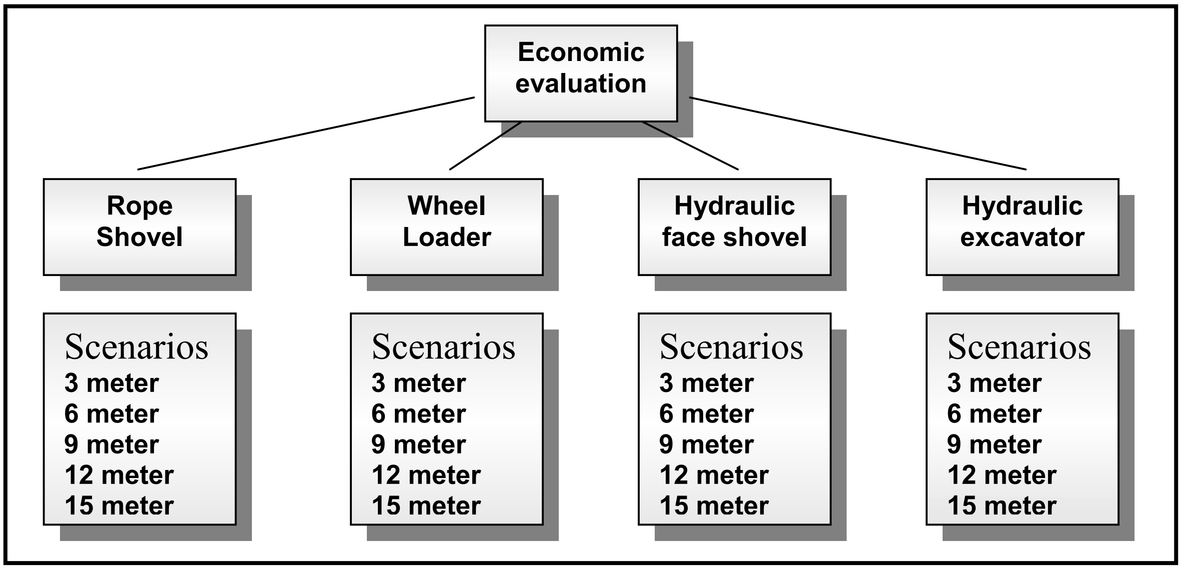


Figure 5.1 Financial evaluation scenarios

5.2.2 Implementation Date, Phasing in and Evaluation Period

Since Thabazimbi is an operating mine, an implementation date for mining activities is not applicable. For the purpose of economic evaluation however, an implementation date was assumed as June 2004. The project will commence in June 2004 with all the relevant capital being spent in that financial year. This implies that stripping will also start in 2004. Based on sufficient available reserves the evaluation period of the project will range from 8 to 13 years, depending on the mining recovery as indicated in table 5.2. The feasibility is quoted in 2003/2004 financial terms.

Table 5.2 Projected life of mine for different scenario's

Scenario	**Reserve (t)**	**ROM per annum (t)**	**Life of mine (years)**
3 m Bench height	24,375,000	2,000,000	12.18
6 m Bench height	22,445,000	2,000,000	11.22
9 m Bench height	20,530,000	2,000,000	10.26
12 m Bench height	18,430,000	2,000,000	9.22
15 m Bench height	16,780,000	2,000,000	8.39

5.2.3 Projected market

The mine produces to a fixed market created by local steel mills. A market demand of 1.7Mt product per annum will be satisfied, which implies 2Mt run of mine per annum at a plant yield of 85%.

5.2.4 Physical Plans as Basis for Cash Flow

The physical production plans are based on the fixed market demand of 2Mt run of mine product per annum. The stripping ratio varies according to the mining recovery achieved as indicated in table 5.2. A constant stripping ratio equal to the average stripping ratio of the scenario was assumed to eliminate the need for detail production scheduling. It is important to understand that increased recovery changes the stripping ratio as previously classified "waste" is now mined as ore. Two different approaches can be followed:

1. Maintain the waste stripping rate and open up more ore at the lower striping ratio, taking advantage of higher sales volumes.
2. Take advantage of the lower stripping ratio, lowering the stripping rate but maintaining the product output, taking advantage of lower production costs.

This economic evaluation will use the second scenario since the market is fixed and no additional sales can be realised (refer to appendix F for detail production plans developed for the analyses).

5.2.5 Macro-Economic Assumptions.

Cash flow items (capital and operating costs) have been adjusted to a common price base and then escalated to time of spending, using escalation rates as indicated in addendum F.

5.2.6 Tax Implications

Tax allowance of 100% of capital in the year of spending was taken into account and tax payable calculated at a corporate tax rate of 30%

5.3. Capital

A new mining project requires extensive capital outlays including equipment, infrastructure, services, beneficiation plant etc. This economic evaluation however includes only the capital required to purchase the drilling and load and haul fleet. The purpose of the evaluation is not to determine the total economic feasibility of the project but rather to indicate the advantage gained through the correct equipment selection. All other capital is assumed to be equal for each scenario and will thus not influence comparison (see appendix G for the capital schedule).

Depreciation of the capital assets will be performed over the relevant life of mine for each scenario. The expected economic life of the plant is in excess of 13 years and no replacement of the plant will be required within the evaluation period. Equipment replacements are carried out with no trade in discount and only new replacements were considered.

5.4. Working Capital

Incremental working capital has been estimated as follows:

- Stocks of final product: 30 days production valued at production costs.

- Debtors: 60 days production valued at sales value

- Creditors: 30 days production valued at production costs (excluding labour).

- Cash on hand: 30 days operating expenses

Only the initial take-on values and thereafter the incremental working capital have been taken into account.

5.5. Operating and maintenance costs

Operating and maintenance costs were calculated from first principles as indicated in Table 5.3. A distinction was made between loading costs and other mining costs. The loading costs will vary with the loading equipment selection and also per bench height. The other costs include drilling, blasting, hauling, and secondary costs and will be calculated for each bench height and will remain the same irrespective of the loading equipment used. The assumption was made that the same haul trucks will be utilized for each of the shovel types, based on the similar bucket sizes. In practise the shovel selection and hauling costs are very closely related. This is because of the principle of equipment matching which determines the haul truck size based on the shovel parameters. Manpower requirements were calculated and adjusted according to the haul truck, shovel and drill rig requirements (see appendix H for the detail calculations). The total production cost is very sensitive to the blast design and the loading costs, which in turn are very sensitive to the production rates at different bench heights. The production costs were calculated in South African Rand and escalated on the South African production price index.

Table 5.3 Cost calculation process

Operating Costs	
Loading costs*	
Other costs	
Hauling	Based on production rate of shovels
Secondary	Based on bench heights
Drilling and blasting	Based on blast design**

*Loading costs are calculated for each shovel type and then adjusted, based on the production rate per bench height scenario

** A blast design is done for each bench height. Refer to appendix I

5.6. Revenue

The prices were based on US$ prices as per contractual agreement and were escalated on the USPPI index, based on the market described in 5.1.3.

5.7. Results of evaluation

It has been determined in chapter 3 that significant potential exists at Thabazimbi for an improvement in ore recovery. The discussion in chapter 4 indicated that each shovel type is most suited to a specific production environment. The question that remained to be answered was which combination of bench height and shovel type will add the most value to the mining project. The results obtained from the economic evaluation will shed more light on this. Refer in addition to appendix J for the full results. The discussion that follows summarises the full results therein.

5.7.1 Production cost variation

The operating cost (R/t) increases with a decrease in bench height. This was to be expected since efficiency in the drilling and blasting is drastically reduced and the production rates decrease. The amount of secondary work in terms of floor cleanup, bench preparation, etc. also increases as the volume of material per floor surface decreases. The results support the general belief that higher benches support higher production rates and thus reduced operating costs. Figure 5.2 shows the operating costs per ton handled.

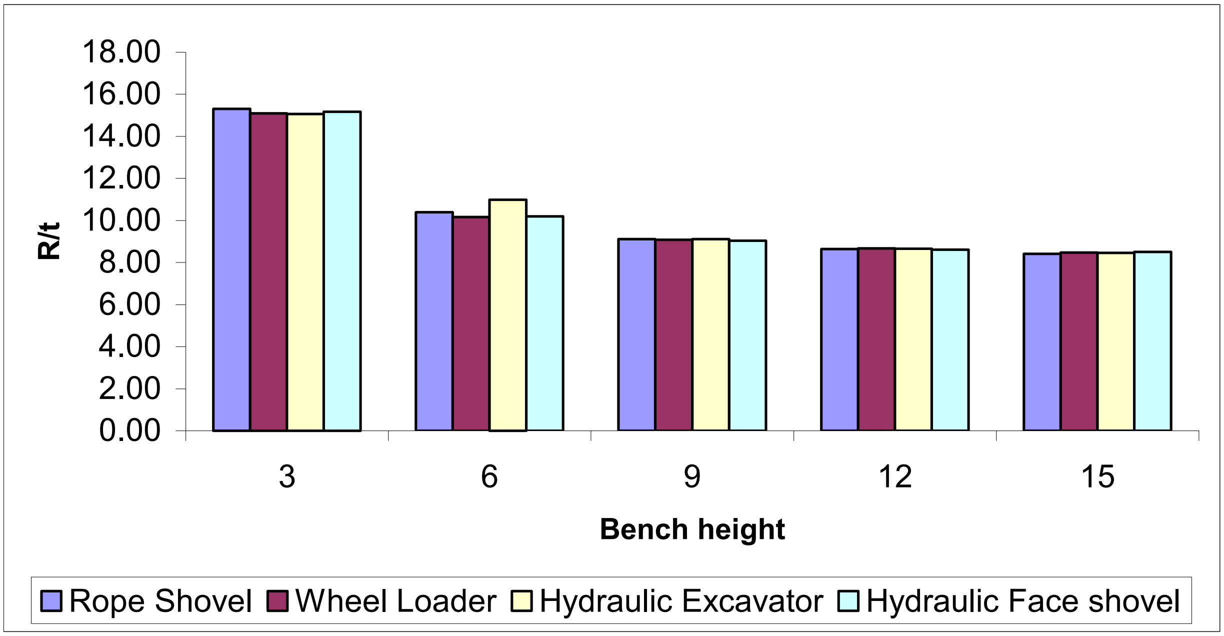


Figure 5.2 Operating cost per ton handled at different selective mining bench heights

However, if we study the cost per ton saleable product, it can be seen in figure 5.3 that the benefits derived from the higher bench heights are absorbed by the lower recovery and hence higher stripping ratio. This is true for all except the face shovel. The reduced production costs at higher bench heights are not withstanding the fact that the stripping ratio increased from 8.45 to 12.72 due to mining losses, making the lower costs even more significant for the face shovel. This cost curve is the foundation of the NPV calculation and hence the same pattern will be observed.

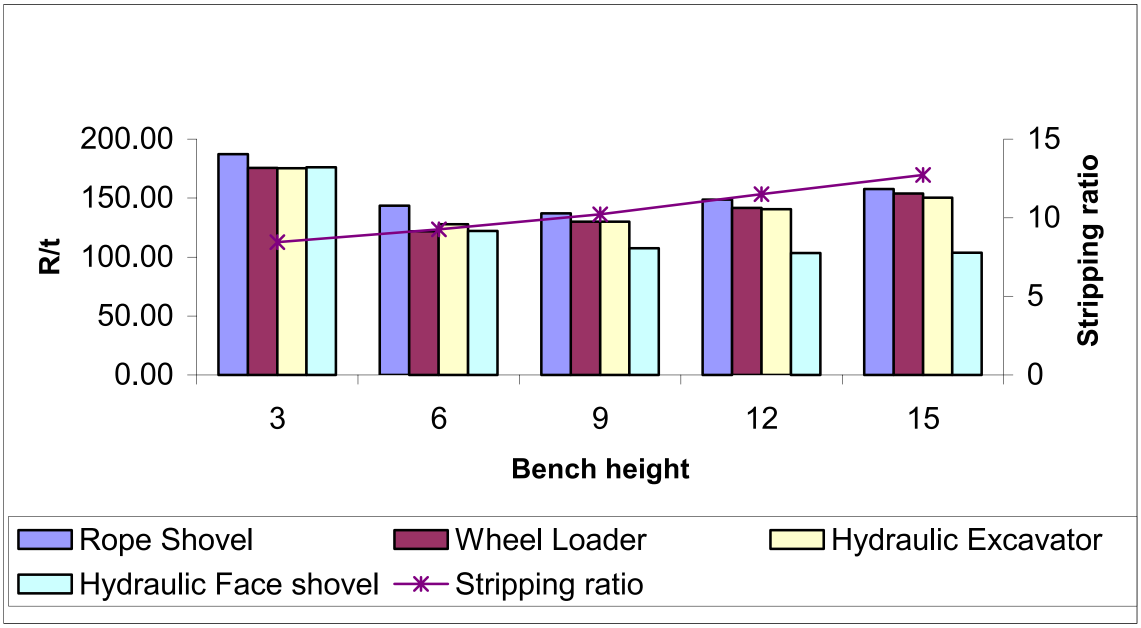


Figure 5.3 Production cost per ton saleable product at different selective mining bench heights

5.7.2 Net present value variation

The net present value of each scenario was calculated by subtracting the initial investment from the cumulative cash inflow, discounted at a rate equal to the cost of capital. This means that the capital outlay in the beginning and the amount of ore recovered to generate cash inflow, are the determining factors in NPV calculation. A mining operation can be compared to a unique manufacturing plant. The product is the run of mine ore. The uniqueness is in the fact that it has to operate between the boundaries of a fixed price and largely predetermined operating costs. The selling price is often fixed by outside market players and the input cost is largely determined by natural factors such as ore yield, stripping ratio etc. The challenge is to produce below the selling cost, in such a way that value is not destroyed over the long term.

The operating cost scenario will emphasise the higher bench heights and lower operating cost which will strengthen short-term results. The NPV however tells a different story. Figure 5.4 indicates that, except for the face shovel, the NPV is almost halved when increasing the bench height from 6m to 15m. This is despite a reduction of almost 43% in operating costs. Why does the face shovel behave so differently? The reason is solely because of its ability to maintain the selective loading ability while gaining the advantage of lower production cost at a higher bench height.

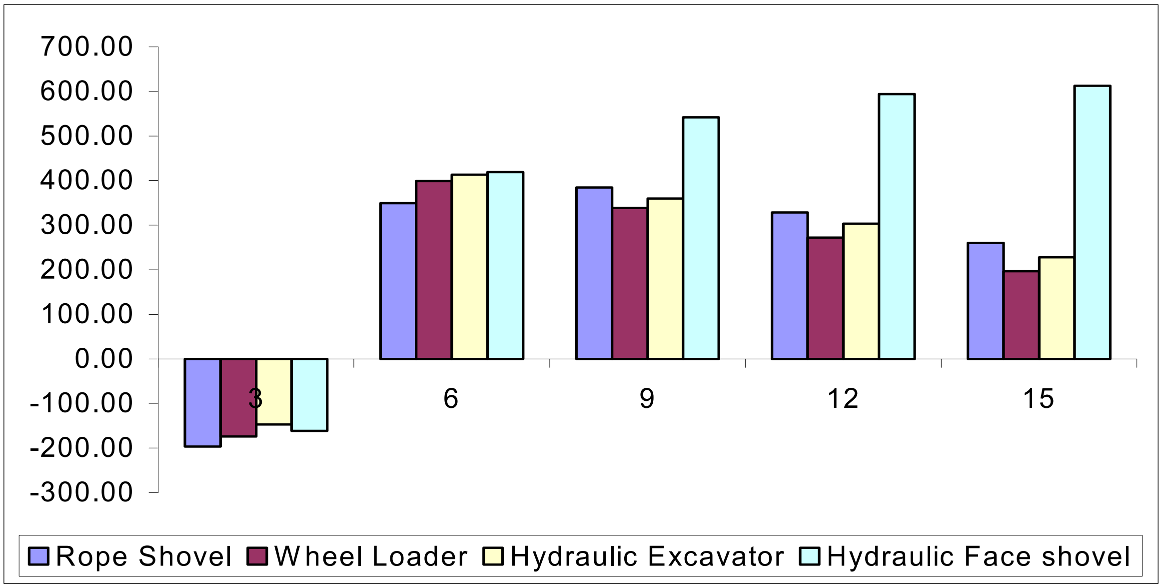


Figure 5.4 NPV at various bench heights for each shovel type

The reason the NPV reduces for the majority of the shovel types, is due to the lower mining recovery. The saleable ore is reduced by 31% whilst the stripping ratio is increased by 50%. The implication of the result is that larger tonnages are mined at a lower cost, but for lower overall returns. Figure 5.5 illustrates these comparisons.

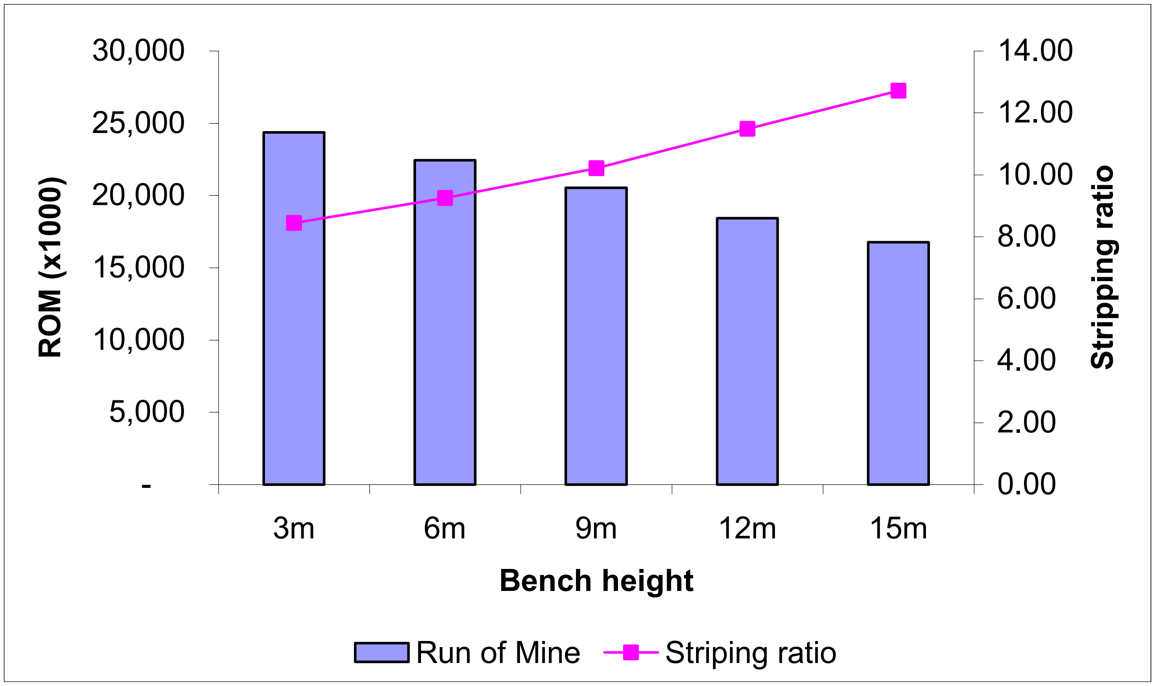


Figure 5.5 Comparison of reserve tonnage to stripping rate

Referring to the performance of the different shovel types on the various bench heights, it can be seen that there exists an optimum application for each. This is largely due to the influence of bench height on the shovel's ability to perform selective loading. Other factors that cannot be ignored are the influence on production rate and even depreciation period of the extended life of mine due to better recovery.

It seems from the discussion that a lower bench height is more desirable in terms of recovery, but that the value of the project can be increased through correct equipment selection. Figure 5.6 shows the best NPV performance at each bench height. While the hydraulic backhoe performed the best on the 3-meter bench height and the same as the face shovel on the 6-meter bench height, the face shovel outperformed the others the rest of the way. It proves that it is possible to add value in the long term while addressing the short-term production cost issues. The negative NPV at the 3-meter bench height indicates that the operating cost is so high that it eliminates the advantage gained from better recovery and causes the project to be uneconomic.

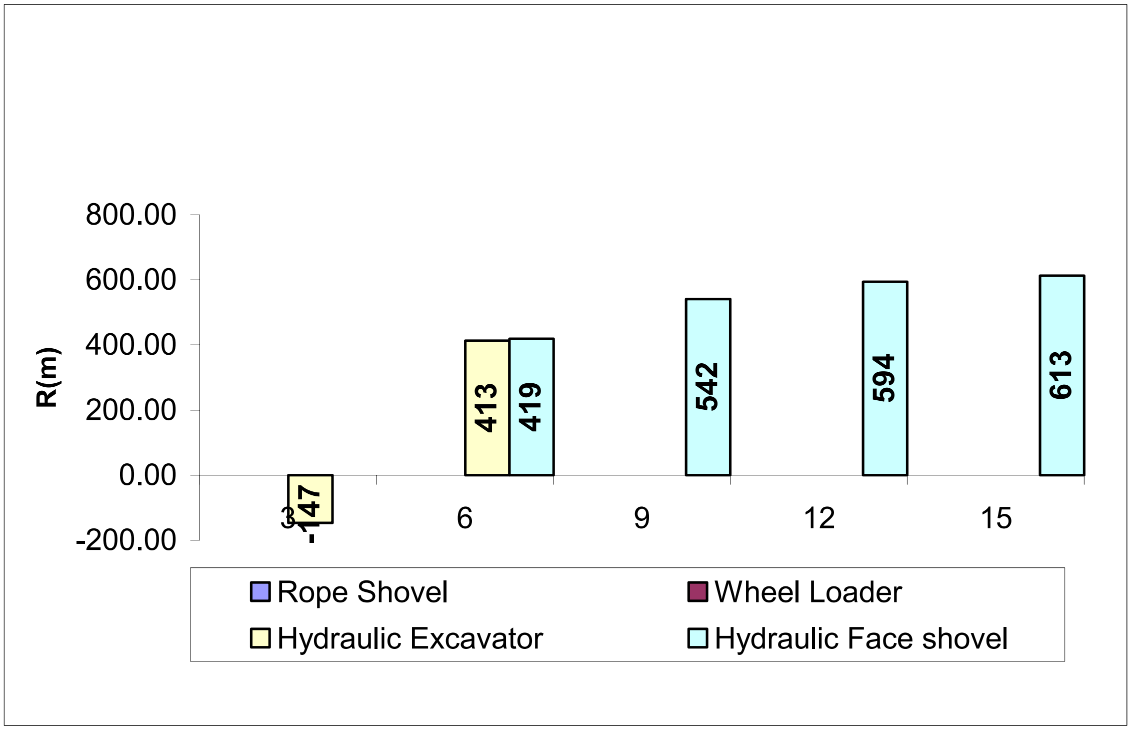


Figure 5.6 Best NPV at each bench height

From the foregoing, it would appear that the rope shovel, which traditionally produces at a low operating cost, is no longer cost efficient in this application scenario. It is because it has been determined previously that the ore body can be classified as a selective ore body which means that potential mining losses or gains will have a material influence on the economy of the project. It is for this reason that the non-selective mining equipment (typically the rope shovel) cannot compare with the hydraulic shovels in terms of selectivity and applicability.

5.7.3 Internal rate of return variation

The IRR is defined as the discount rate that equates the present value of cash inflows with the initial investment. In other words, at what cost of capital will the NPV be equal to zero? Figure 5.7 compares the different scenarios in terms of IRR. It is clear that a high initial investment impacts negatively in the IRR, as can be seen in the rope shovel scenario. The wheel loader shows a consistently high IRR regardless of lower cash inflow because of the low initial investment and a depreciated investment in future. This evaluation where only the capital outlay of the equipment are considered favors the low investment scenarios. In practice, where a high capital investment is required regardless of the equipment type, the scenario that generates the highest cash inflow over the longest period of time will be at a significant advantage. Finally it is recognized that some of the IRR figures are high, which can be attributed to the limited capital and operational costs included in the evaluation. This should not influence the comparative accuracy, since all scenarios were treated equally.

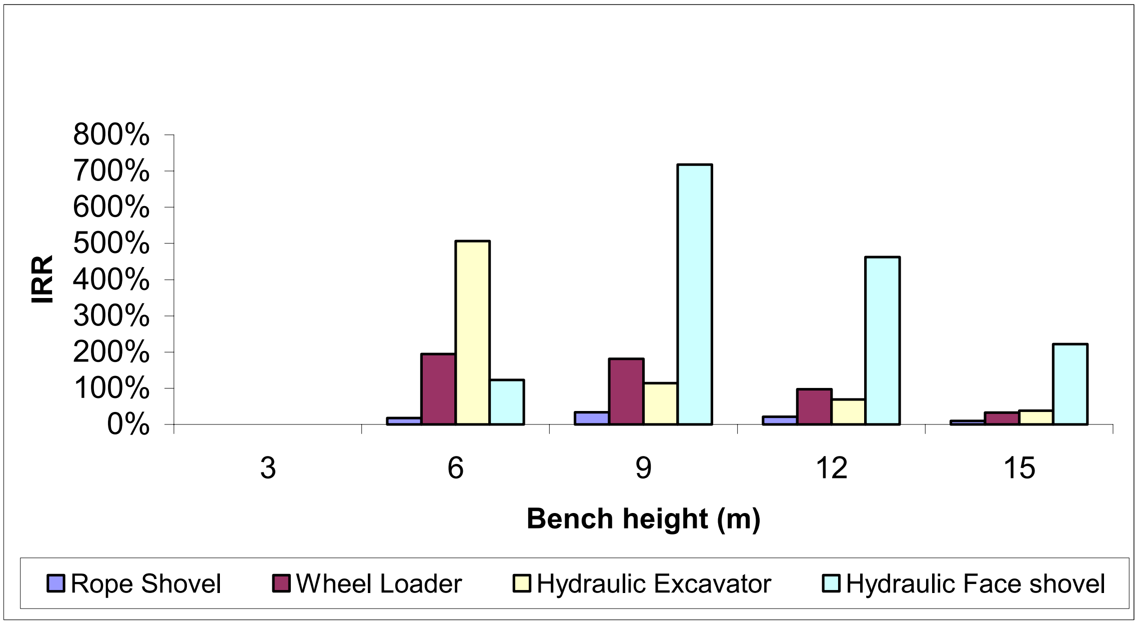


Figure 5.7 Comparative IRR variations with bench height

5.8. Conclusions

In conclusion, the following observations should be highlighted:

The operating cost is sensitive to bench height and shows a 50% reduction through an increase in bench height. From 3m to 15m.

The production cost per ton of saleable product generally is the lowest at 6m bench height but increases with a further bench height increased due to reduce mining recovery.

Each shovel performs optimally under different conditions.

The IRR is sensitive to initial capital expenditure and the ability to generate positive cash flow over a sustained period of time.

The best mining recovery is achieved at 3-meter bench heights and the worst at 15-meter bench heights. Unexpectedly, the best NPV is attained at a mining height of 15m and the worst at 3-meter bench heights. The difference in NPV is dramatic. R192m in the negative compared to R612m positive value. The reason is because of the ability of the face shovel to take advantage of 3m selectivity while maintaining the cost advantage of 15m bench heights. This is what makes the difference between adding value and destroying value.

This is a snapshot of one specific combination of assumptions and parameters. Various alternatives are possible to either increase the possible advantage or extend its applicability to other situations. These alternatives will be discussed in chapter 6 from a practical perspective.

6 PRACTICAL IMPLEMENTATION ISSUES

6.1. Introduction

The preceding discussions and evaluations investigated the potential for value addition to the mining project through bench height variations to improve mining selectivity. It was determined that substantial potential exists in selective ore deposits to increase mining recovery and hence economic potential of the project. In this specific analysis the results were dramatic because of the geometry of the ore body. This was a glimpse into the very complex and iterative process of mine planning and scheduling. Alternative approaches and scenarios exist for each of the sub-processes identified in chapter 2.2. These alternatives can be investigated to either increase the potential of the project or to make the application of these principles more applicable to any given set of circumstances. These alternatives scenarios and sub processes are summarised in Table 6.1.

Table 6.1 Alternative evaluation scenarios

Sub process	**Alternative scenarios**
Resource identification	Fixed
Corporate objectives	Fixed
Mining Method	Fixed
Block model	Investigate smaller equipment down to $6m^3$. Apply bucket size to block model.
Economic optimisation	Increased pit size due to better mining recovery
Detail design	Use different bench heights for waste and ore mining Incorporate smaller truck dimensions due to smaller equipment into pit design
Production Scheduling	Use different shovels for waste and ore loading Focus on matching of equipment, taking into account haul distance.
Budget	Capex advantage gained from lower plant capacity due to better selective mining
Reserve Base	Fixed

The application and possible benefit from each of these alternative scenarios will be discussed briefly.

6.2. Alternative Scenarios

6.2.1 Block model construction

The construction of the block model for evaluation processes occurs in the beginning of the planning process as indicated in figure 2.1. The current evaluation simulated different types of shovels all within the 15-19m^3 range. It was established that the geometry of the mining block is not as important as the actual volume of the block. A sensitivity analyses on the block size indicated that potential still exists to improve on recovery through a further reduction in block size to 2m x 2m (see figure 6.1). This would not necessary mean a reduction in shovel size, but rather in dipper size. Maintaining the longer reach of the larger boom and dipper stick will allow the shovel to take advantage of the higher bench height in terms of production cost.

The impact of either a smaller dipper or smaller shovel on the truck selection should also be addressed and will be discussed in the detail pit design and production scheduling processes.

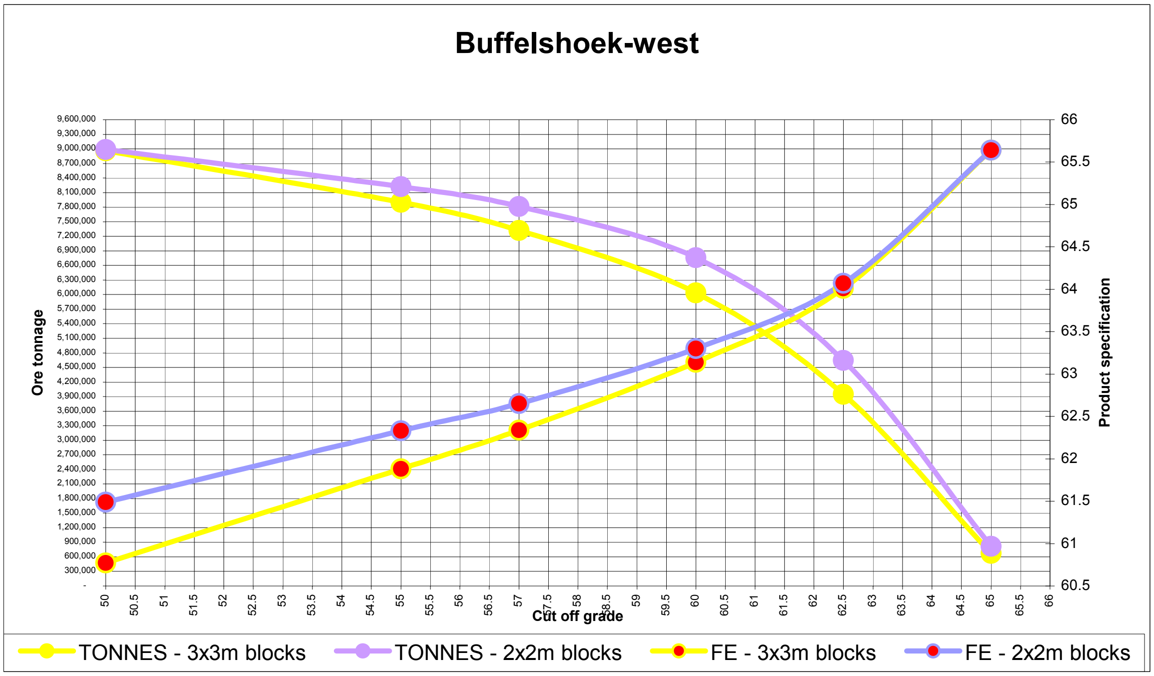


Figure 6.1 Potential of smaller shovel size for increased recovery

6.2.2 Economic Optimisation

The principle of economic pit optimisation was discussed in chapter 2. It was stated "…*by assigning a value to each and every block generated in the block model and calculating the combination of blocks that will achieve the highest value. The calculation is very sensitive to production costs, pit slopes and income generated".* A reduction in block size will lead to a reduction in dilution, causing more blocks to exceed the cutoff value, and thus generate income as ore. This means that the monetary value of the previously selected combination of blocks will now be higher, which will lead to either of 2 scenarios that will be explained by means of an example.

Scenario 1

The optimization calculates the combination of blocks that will deliver the highest monetary value. This means that the next incremental cut, as shown in figure 6.2, must increase the value of the total combination in order to be included in the optimum pit shell. If the change in ore recovery in this incremental cut causes the value to become positive, the increment will be included and the volume of the optimum shell will increase, increasing the available ore.

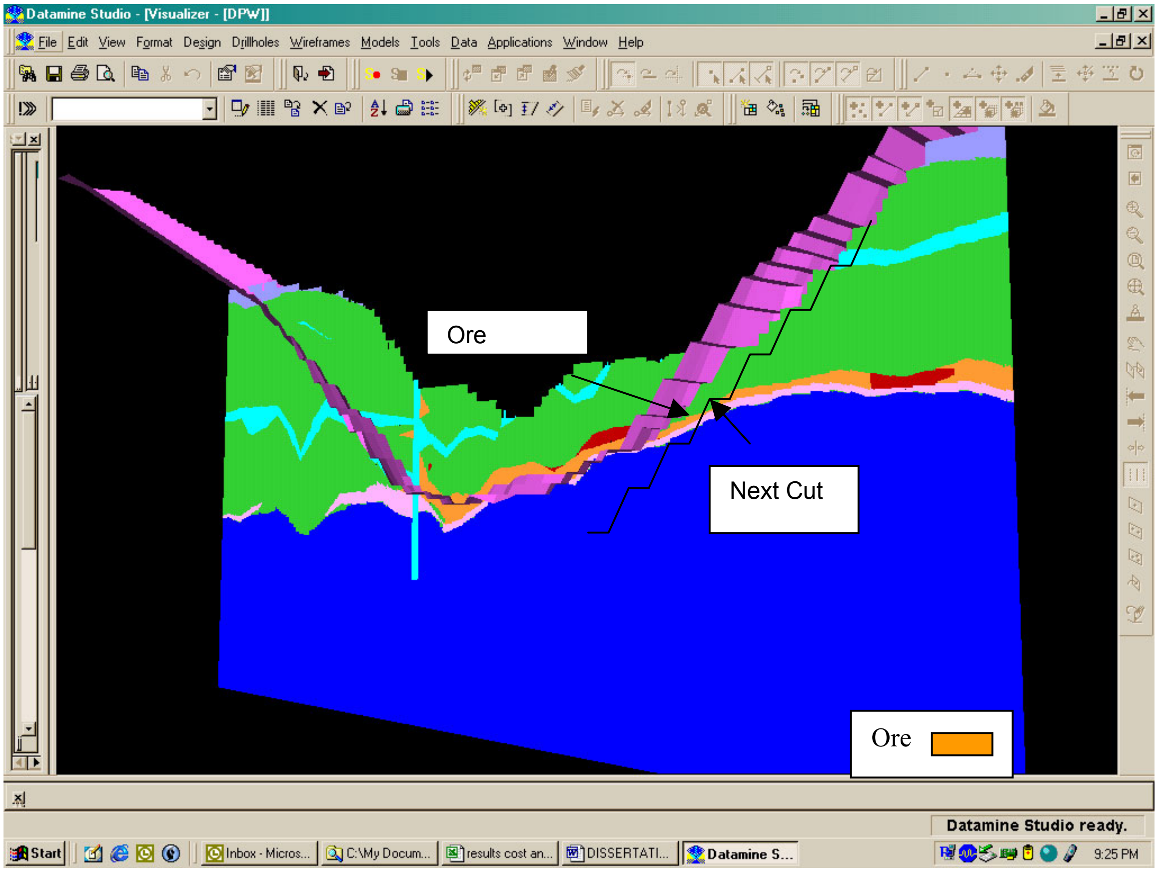


Figure 6.2 Incremental evaluation of the optimum pit shell

Scenario 2

The profit/tonnage curve generated by the optimization process is shown in figure 6.3. The optimum combination of blocks is reached at point A on the graph. It means that if the pit shell is increased or decreased in size, the total profit will decrease. If the monetary value of that same pit shell increases due to better recovery within the optimum shell, the optimum pit shell will shift to point B. The decision can now be made to stay with the current pit shell and take advantage of the higher profit or alternatively the initial profit can still be maintained with an increased life of mine as indicated at point C. The final decision will be based on corporate strategic objectives as discussed in chapter 2.

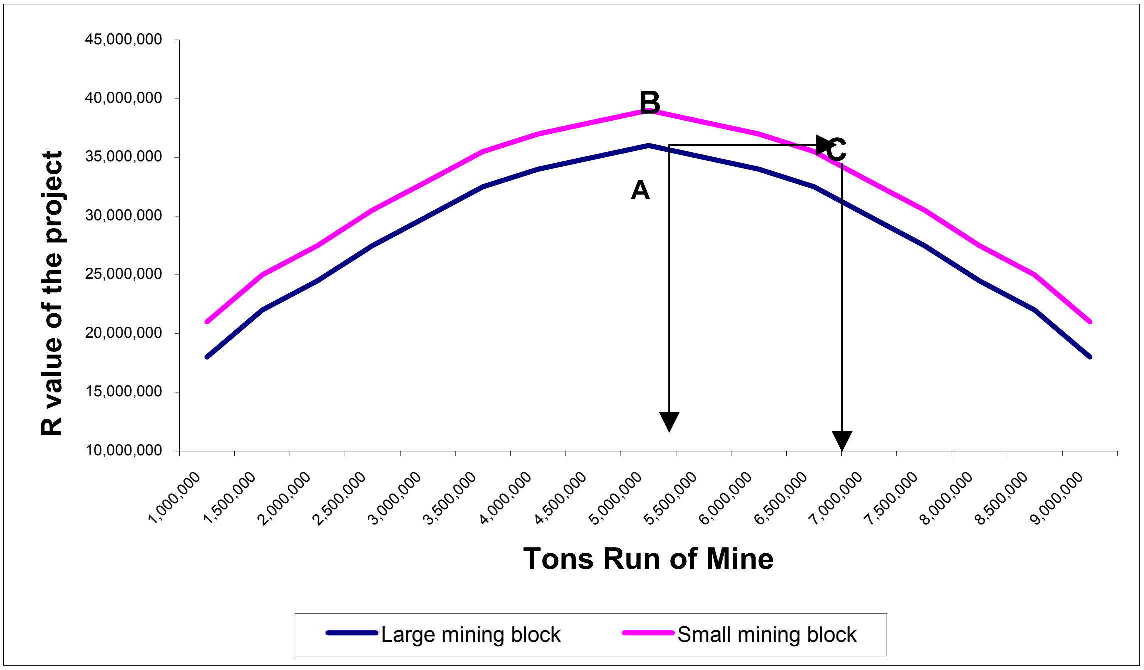


Figure 6.3 The optimization profit / tonnage curve indicating various strategic scenarios

6.2.3 Detail pit design

The detail pit design is based on the economic optimisation. Optimisation parameters and the block model therefore also determine the bench height. An assumption that should be tested is that all waste and ore should be loaded from the same floor level. It is often very simple to design sufficient access to different elevations in order to load waste and ore at different bench heights. This could compensate for equipment inability to load selectively at higher bench heights. Hence the advantage of higher benches can be utilized on the waste stripping simultaneous to achieving better ore recovery. This option should be considered in an established mine where the equipment is pre ordained.

Another advantage that can be gained during the pit design phase is based on smaller equipment and specifically, smaller haul trucks. The economy of scale is lost when selecting smaller haul trucks and the impact will be increased if long hauling distances are applicable. But the long-term advantage/disadvantage must be calculated in order to make an informed decision and this includes the pit design. Pit design standards prescribe that a haul road should be 3 to 3.5 times the width of the haul truck. When selecting a smaller truck to match the smaller dipper size, the difference in width could be in excess of 1m. This implies reducing the road width with up to 3m. Also, using smaller turn radii could generate further savings in waste stripping if the pit design consists of several levels, thereby possibly compensating for the increase in hauling cost.

The importance of the value chain approach is emphasized in this scenario. The most economic equipment selection decision cannot be made if the total impact on the value chain has not been determined.

6.2.4 Production Scheduling

If the pit design does not allow for split-levels and the equipment fleet is predetermined, the use of alternative ore loading shovels can be investigated. This is a suitable option in a high stripping rate operation. High production rate shovels can be utilised on the waste and more specialised shovels on the ore. Utilisation of the shovels might be lower than required for successful financial motivation but the total cost benefit in terms of NPV must be considered.

If smaller shovels or dipper sizes are justifiable, the concept of equipment matching has to be applied. Standard equipment selection practice will indicate that the haul truck size will also be reduced to maintain the general rule of 3 to 5 passes to fill a truck. If very long haul distances are applicable, this general rule should be reconsidered. Various simulations can be used to indicate when it is more economic to use larger trucks, compromising on the loading time of an already long cycle time, to gain on the longer hauling cycle.

6.2.5 Budget

One aspect, which has not been addressed, is the influence of selective mining on plant capital budgeting. The plant feed rate is an important parameter in the detail design of any plant. The plant feed rate is determined by the required output and the calculated plant yield. Selective mining will determine the type of plant feed and ultimately influence the plant yield attained. By introducing the selective mining results early into the project planning, significant savings can be realised on the capital expenditure of the plant.

6.2.6 Summary

Whilst it is impossible to identify all scenarios applicable to a diverse mining project, it is important to revisit the generic mine planning process as set out in figure 2.1. Adding the resource evaluation process as suggested in figure 3.11 to the planning process can assist in ensuring that process is aligned to add maximum value during the planning phase as shown in figure 6.4. If the simulation indicates that the ore deposit should be classified as selective, the equipment selection process should be conducted as indicated in figure 4.11, exploiting every opportunity to add value through selective mining. If the simulation indicates that a material difference cannot be made through selective mining, the focus should be on economy of scale, selecting the equipment that will yield the highest production rate at the lowest cost.

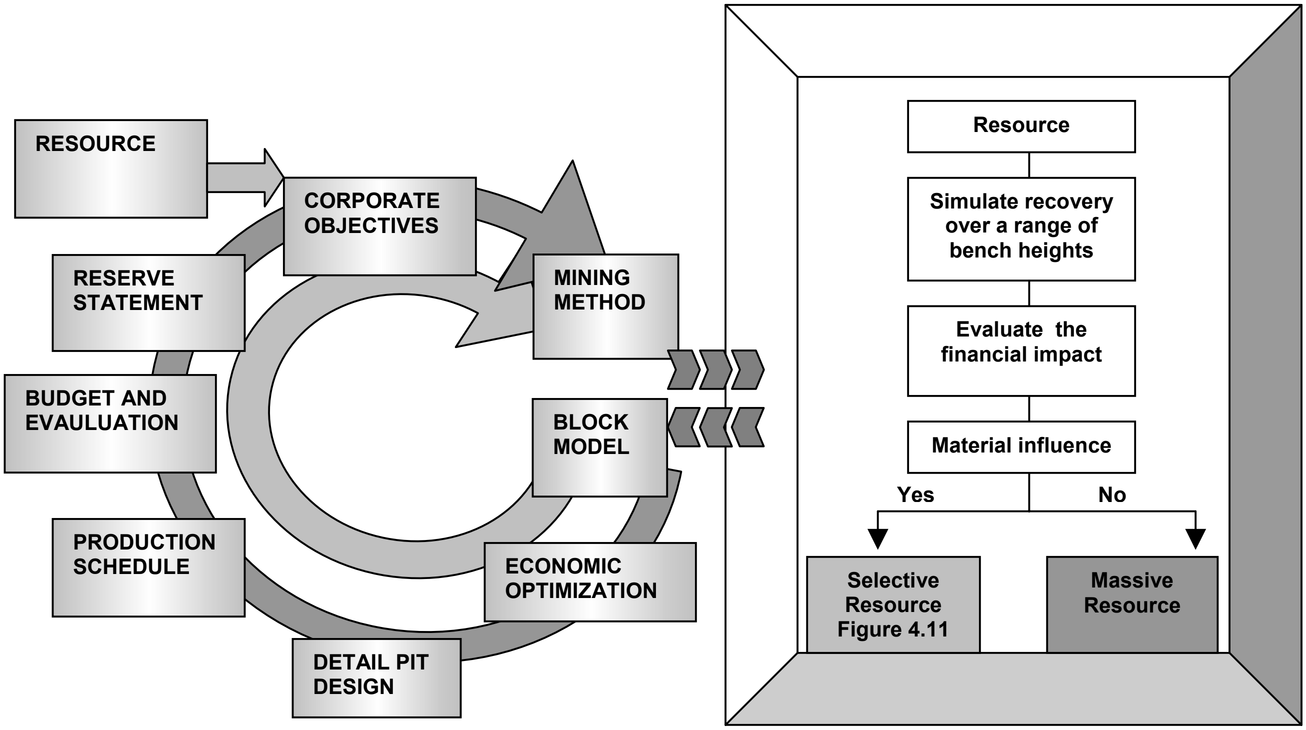


Figure 6.4 Revised mine planning process

7 CONCLUSION

This dissertation addressed the influence of bench height and equipment selection on effective mineral resource utilisation. The objectives of the study were to develop a systematic approach that can be used in the evaluation of a wide range of reserves in the initial planning phase to determine the most economic bench height and equipment selection. The following conclusions are offered;

7.1. The current practice in equipment selection methods

Various approaches exist to address equipment selection, ranging form classical and operations research to artificial intelligence. The primary focus of these methods is equipment matching, production rates and equipment allocation. Although bench height and selectivity has been identified as key parameters in the equipment selection process there is no evidence that the full potential of resource utilisation is quantified in order to determine the optimum bench height and equipment configuration. An analysis of the worldwide trend in shovel population supports these findings since any increase in a market share category is at the expense of the next bigger category of shovels, and a decrease in units per category is offset by a further increase in capacity. There is no evidence in the market that effective resource utilization are applied by the end user and these requirements are thus not passed on to the manufacturer to respond to.

This study highlighted the need for a revised approach, matching the ability of the shovel with the characteristics of the ore deposit. A revised mine planning process was developed based upon the structured recognition of selectivity and financial materiality. This should be incorporated in the traditional mine planning process and will allow the mining engineer to evaluate and classify the ore deposit before equipment selection commences, ensuring that the equipment selection process focuses on the real value drivers.

7.2. The correlation between ore body geometry, bench height and mining recovery

The extent to which selective mining can be applied is influenced by various factors, the most significant ones being the geometry and geological complexity of the ore body. The geometry, bench height and simulated mining recovery are very closely related and a thorough evaluation cannot be done without considering each of these aspects. Once the ore deposit has been classified as a selective deposit, it is of paramount importance that a thorough understanding of the deposit is gained before proceeding with the selection process. The geometry of the ore body, the grade distribution and chemical and physical composition of the host rock all play a part in the required ability of the equipment. Just as important is an understanding of the ability of the loading equipment. The supplier and end user should work in close co-operation, ensuring that the demands set by the ore deposit are met. It has been indicated that a 3D simulation of the loading action, based on the geometry of the ore deposit, can indeed be used to determine the economic materiality of increased recovery on the total mining project. Based on the materiality concept the deposit can be classified as either a bulk mining or selective mining deposit.

A simulation procedure was developed which allows for an effective evaluation of the ore deposit, taking into account mining dilution and grade distribution. The results of the Thabazimbi exercise indicated that, compared to a base case of a rope shovel operation at 9m bench height, the reserve can be increased by 18% or 3.84Mt.

7.3. The influence of shovel selection on mining recovery

It is clear from the previous discussions that each shovel has unique features in which it excels above the competition. Bench height plays a vital role in the equipment selection process, influencing both the equipment selection and recovery and dilution. The ability to load selectively cannot be mathematically calculated. It is a judgment made on a thorough evaluation of the design and operating features of the shovel in conjunction with the ore body geometric parameters and the loading face conditions. The efficiency of the selected shovel can be manipulated through the application of different bench heights, and the optimum combination can only be determined through a total value chain costing analyses.

Guidelines were evolved from this work by means of which equipment should be selected if the deposit has been classified as a selective deposit. It is an iterative process, which allows the user to select the optimum combination of bench height and equipment type, taking into account a total value chain costing evaluation.

7.4. Total value chain cost evaluation

The need for a total value chain costing evaluation has been clearly indicated in this work. Any equipment selection decision should be based on a total value chain cost evaluation and not only operating cost per unit handled. Decisions based on operating cost are short sighted and can destroy significant value over the long term. Operating costs are very sensitive to bench height while net present value is generally dictated by mining recovery. The study showed that R230m could be added to the net present value of the Thabazimbi project through the application of a shovel that can achieve high selectivity at high bench heights.

7.5. General conclusions

Equipment selection is not a stand-alone sub-process, but should be conducted with insight into the whole value chain and based on a total value chain costing analyses. The complicated and time-consuming nature of such an analyses emphasises the need for an early opportunity to indicate whether significant value can be added. This should be done as early as the block-modeling phase. The equipment selection process must be adapted for massive and selective deposits, each focusing on the key value driver to add value to the process.

Detail pit design should also take cognisance of the potential advantage of a selective mining scenario. Incorporating smaller equipment specifications into the design standards can increase the value of the project over the long term through a reduction in road width and thus possibly stripping ratio.

It is the opinion of the author that the technical requirements discussed in this dissertation i.e. bench height and equipment selection, should be complimented by a committed workforce, dedicated to total resource utilization and empowered by a collaborative culture. It is only through a team effort, supported by each member in the value chain that real value can be added on a sustainable basis. Ultimately the correct bench height and equipment can only allow the dedicated operator to do more efficiently what he passionately pursues, and that is increased resource utilization.

7.6. Recommendations for further research

The intelligence knowledge based system used by *Clarke et al (1990)* shows the most potential to be developed to take ore body geometry and ore recovery into account to do an automatic shovel selection. The shovel knowledge base and geology knowledge base can be adapted to include specifications and limitations which determines the decision making process.

Very powerful computerised systems are currently available which can be applied to manipulate block model data in a way that emulates mining processes. Although an attempt has been made to do that, the author is of opinion that the process can be developed to suite the needs of a wider range of ore types and deposits. These evaluations can compliment the above mentioned development areas in terms of the knowledge base systems.

Equipment is traditionally evaluated in terms production rate, maintenance and operating costs and capital cost. The need has been identified for a technical evaluation and documentation of the selective loading ability of different types of loading equipment. The result of such a study will allow the end user to make informed decisions on the application of the equipment and will assist in the equipment selection process for selective ore deposits.

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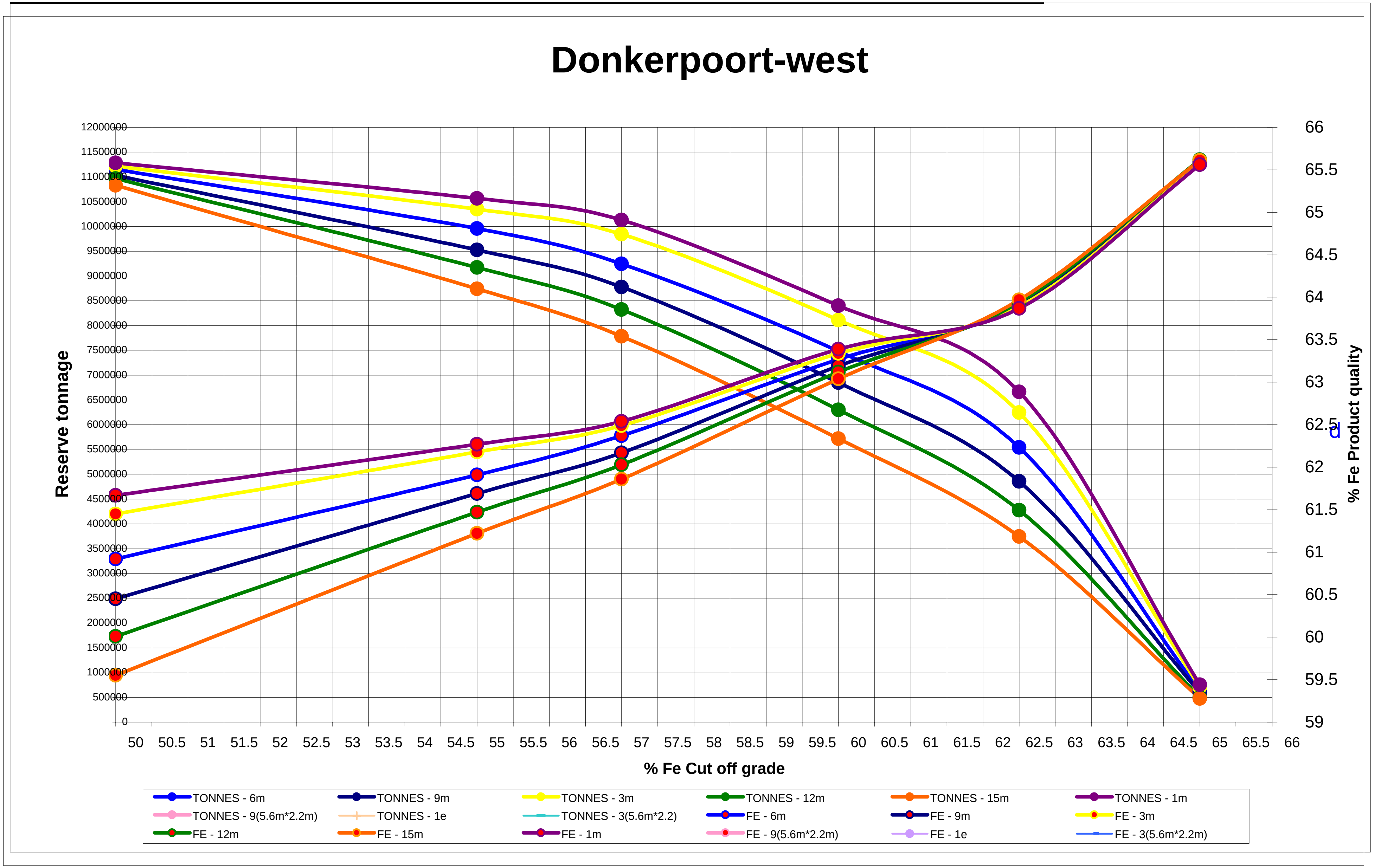
APPENDIX A – SENSITIVITY ANALYSES ON THE VOLUME OF THE EVALUATION BLOCK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TONNES - 3(5.6m*2.2)
FE - 6m
FE - 9m
FE - 3m
FE - 12m
FE - 15m
FE - 1m
FE - 9(5.6m*2.2m)
FE - 1e
FE - 3(5.6m*2.2m)

Donkerpoort-West

		Ore	**Low Grade**	**Totaal tons**
In situ		**10,373,000**	**1,029,548**	**99,458,000**
		Total Ore	**% change**	**Waste**
1 meters		10220000	100%	89,238,000
3 meters		9700000	95%	89,758,000
6 meters		9010000	88%	90,448,000
9 meters		8220000	80%	91,238,000
12 meters		7510000	73%	91,948,000
15 meters		6730000	66%	92,728,000

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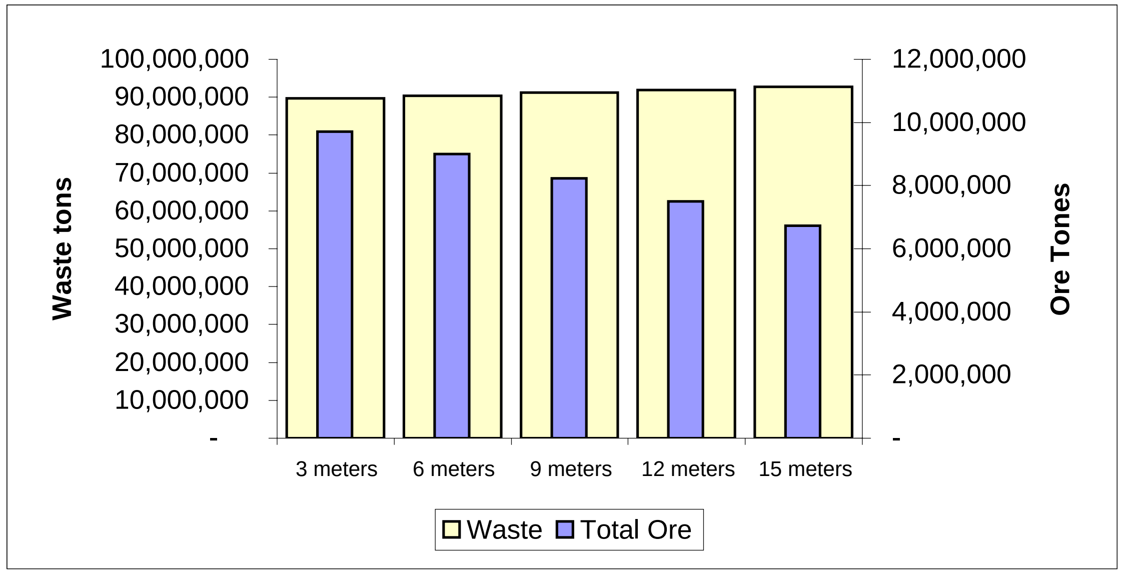
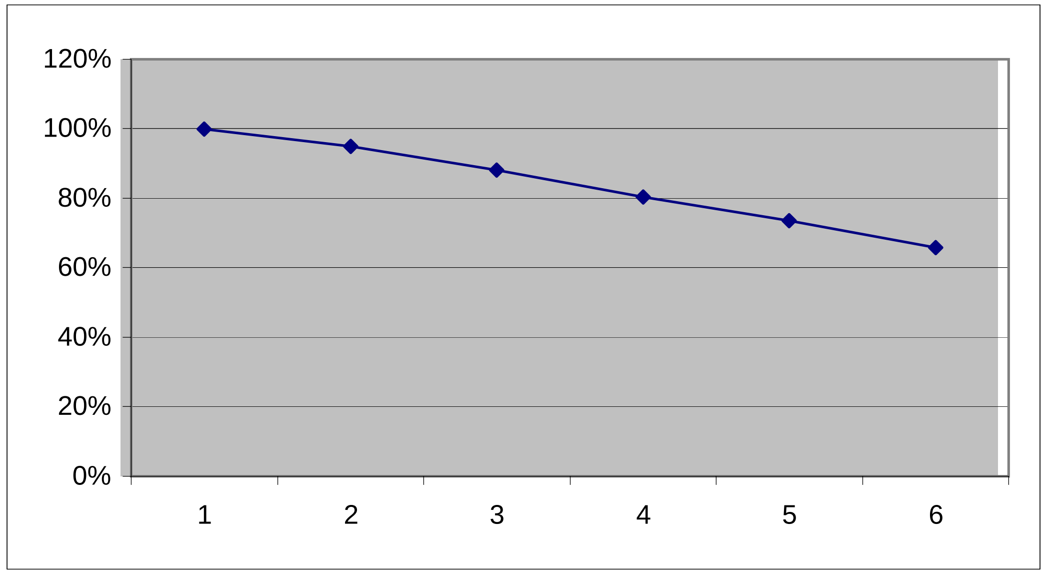
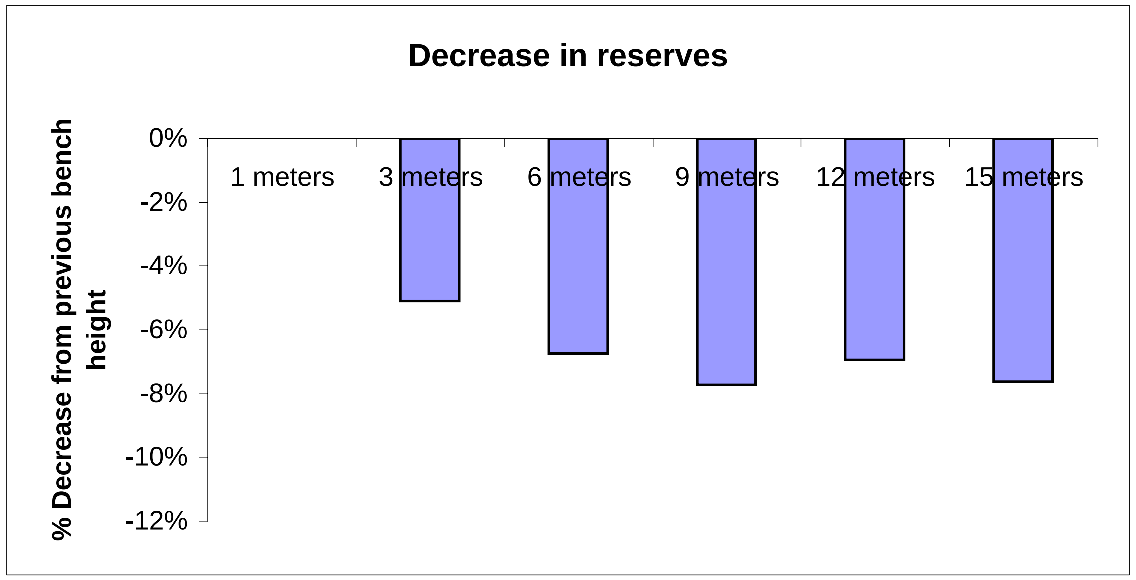
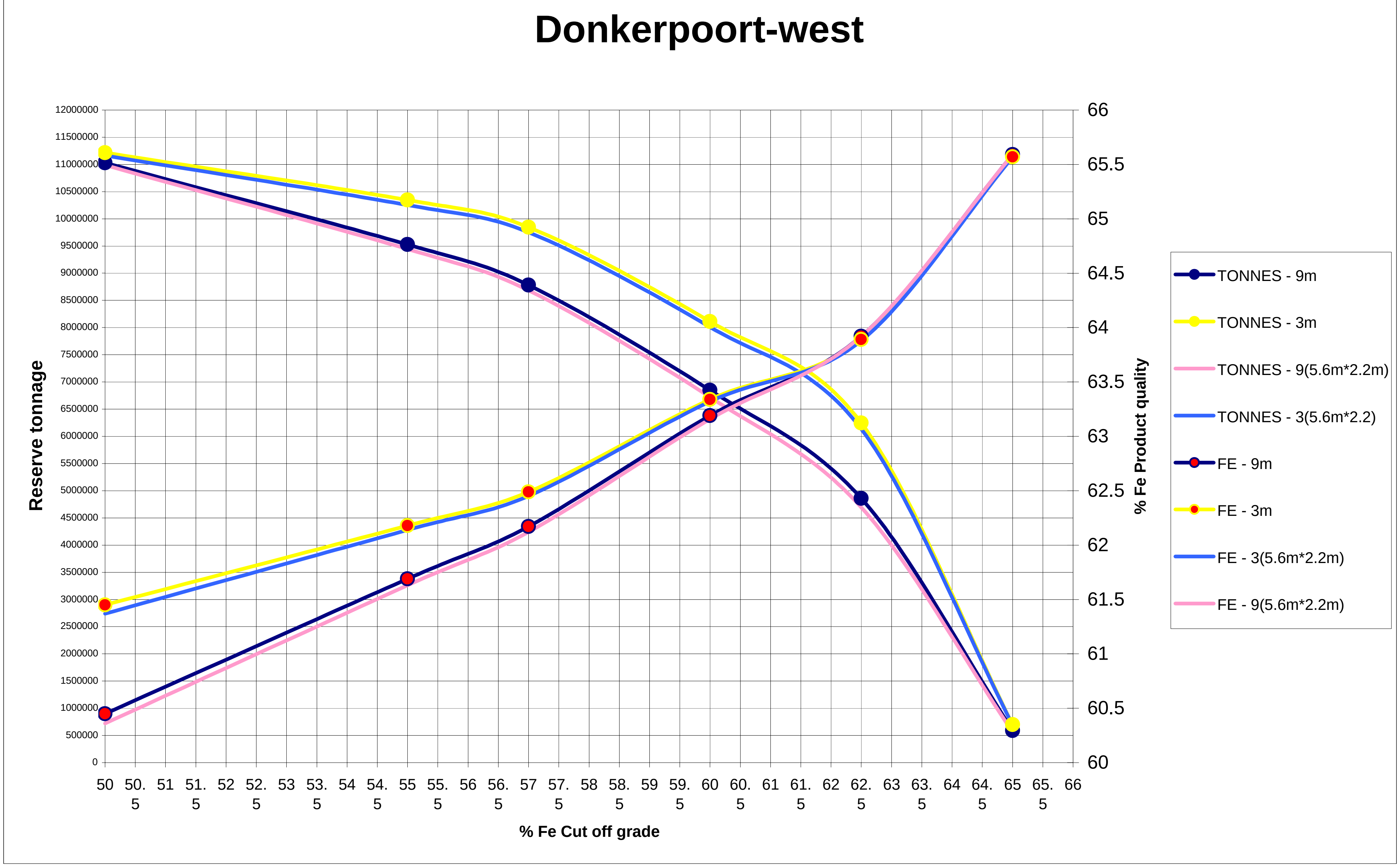
0%
-5.1%
-6.8%
-7.7%
-6.9%
-7.6%







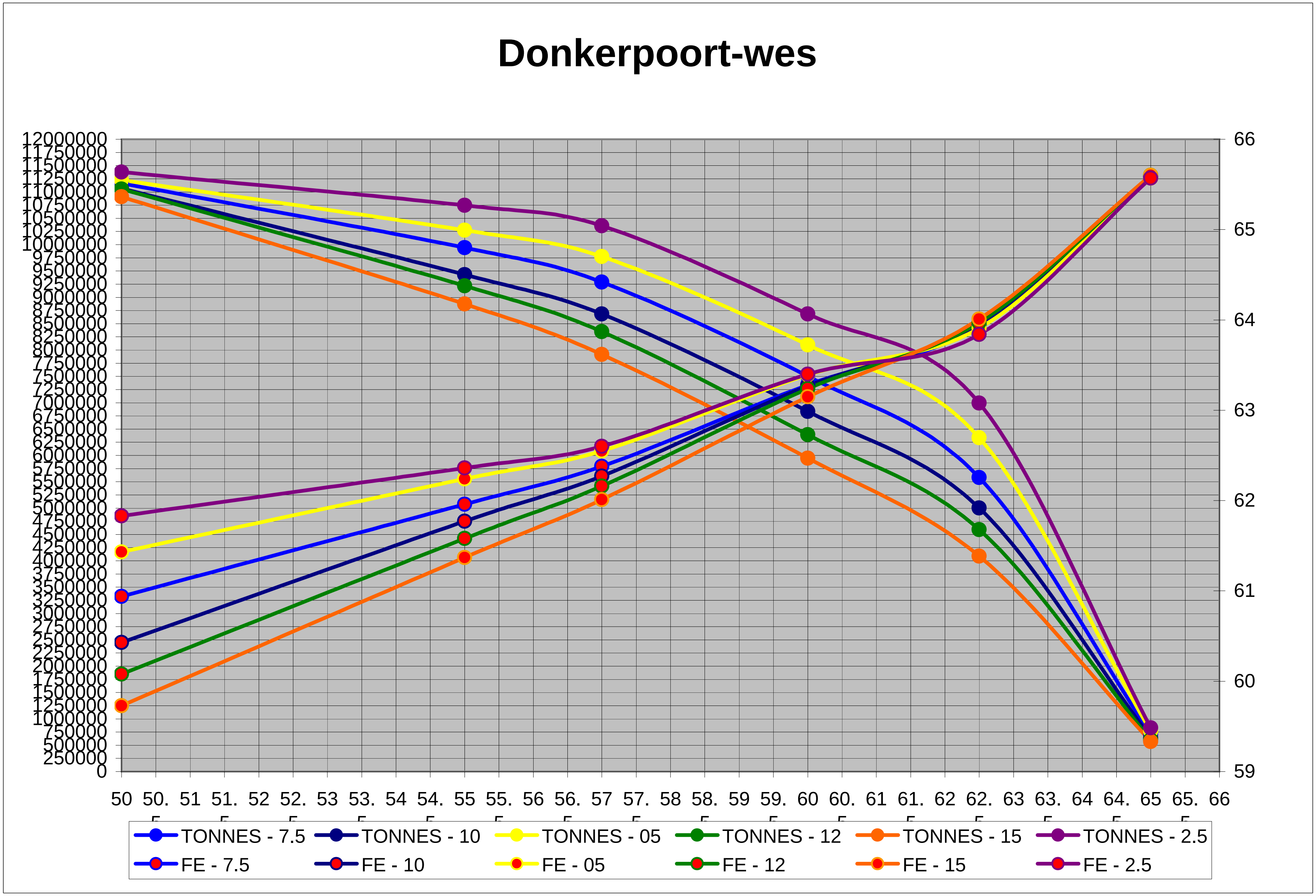

Donkerpoort-west
Reserve tonnage
12000000
11500000
11000000
10500000
10000000
9500000
9000000
8500000
8000000
7500000
7000000
6500000
6000000
5500000
5000000
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
% Fe Product quality
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
61
60.5
60
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
% Fe Cut off grade
TONNES - 9m
TONNES - 3m
TONNES - 9(5.6m*2.2m)
TONNES - 3(5.6m*2.2)
FE - 9m
FE - 3m
FE - 3(5.6m*2.2m)
FE - 9(5.6m*2.2m)

ABOVE	FE - 3m	TONNES - 3m	FE - 6m	TONNES - 6m	FE - 9m	TONNES - 9m	FE - 12m	TONNES - 12n	FE - 15m	TONNES - 15n	FE - 1m	TONNES - 1m	FE - 1e	TONNES - 1e
50	61.45	11213536	60.92	11152535	60.45	11029470	60.01	10964432	59.55	10830029	61.67	11284350		
55	62.18	10347820	61.91	9956295	61.69	9528024	61.47	9172198	61.22	8740682	62.27	10568036		
57	62.49	9844501	62.37	9244650	62.17	8779753	62.03	8321542	61.86	7784983	62.54	10129211		
60	63.34	8111536	63.27	7481641	63.19	6848458	63.12	6298984	63.04	5718482	63.39	8402101		
62.5	63.89	6244649	63.9	5542745	63.92	4857303	63.94	4276479	63.97	3746052	63.87	6662942		
65	65.57	701258	65.59	619573	65.59	588572	65.62	494910	65.61	478155	65.56	753916		

FE - 9(5.6n	TONNES - 9(5.6m*2.2m)			FE - 3(5.6n	TONNES - 3(5.6m*2.2)
60.36	10986364	62.85	10436686	61.37	11164653
61.63	9441491	62.99	10278426	62.14	10254640
62.12	8684731	63.14	10058410	62.45	9752498
63.16	6722574	63.48	9350870	63.32	8007932
63.92	4692069	63.86	7744329	63.88	6134613
65.59	558556	65.55	874482	65.57	692194

14

13.300
12.25
12.32


Donkerpoort-wes
12000000
11750000
11500000
11250000
11000000
10750000
10500000
10250000
10000000
9750000
9500000
9250000
9000000
8750000
8500000
8250000
8000000
7750000
7500000
7250000
7000000
6750000
6500000
6250000
6000000
5750000
5500000
5250000
5000000
4750000
4500000
4250000
4000000
3750000
3500000
3250000
3000000
2750000
2500000
2250000
2000000
1750000
1500000
1250000
1000000
750000
500000
250000
0
66
65
64
63
62
61
60
59
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
TONNES - 7.5
TONNES - 10
TONNES - 05
TONNES - 12
TONNES - 15
TONNES - 2.5
FE - 7.5
FE - 10
FE - 05
FE - 12
FE - 15
FE - 2.5

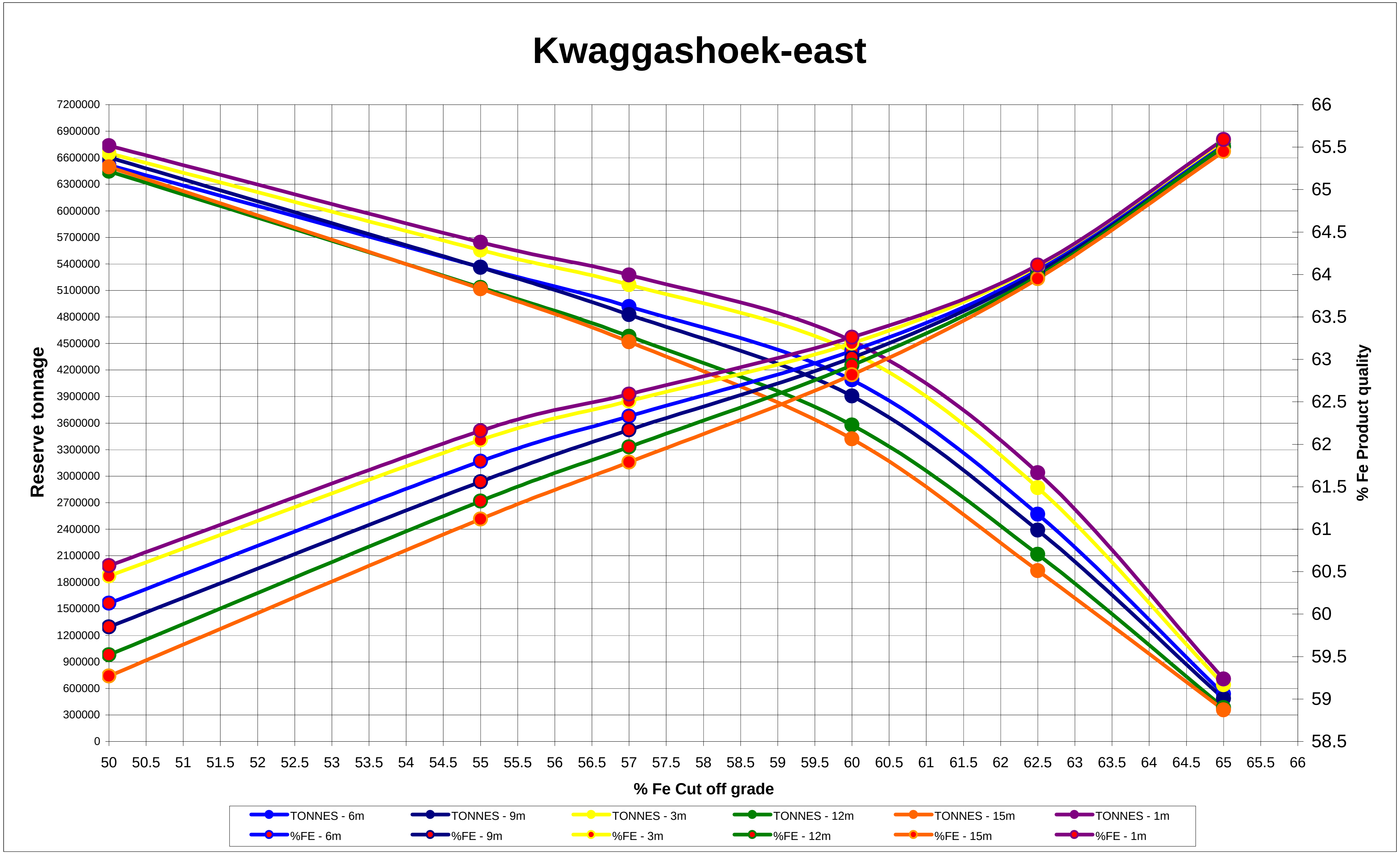
ABOVE	FE - 05	TONNES - 05	FE - 7.5	TONNES - 7.5	FE - 10	TONNES - 10	FE - 12	TONNES -	FE - 15	TONNES -	FE - 2.5	TONNES - 2.5
50	61.43	11228876	60.94	11165457	60.43	11070146	60.08	11056095	59.73	10908178	61.83	11376521
55	62.24	10273559	61.96	9941708	61.77	9432149	61.58	9218260	61.37	8875306	62.36	10746687
57	62.55	9774291	62.38	9289032	62.27	8685656	62.16	8350877	62.01	7916928	62.6	10358416
60	63.39	8095649	63.28	7502677	63.27	6832789	63.24	6393862	63.15	5946976	63.4	8684881
62.5	63.91	6336559	63.93	5581827	63.95	5001369	63.97	4591680	64.01	4088413	63.84	6993264
65	65.57	764794	65.58	710695	65.59	634523	65.6	600906	65.6	570320	65.57	831381

CUT-OFF GRADE TABLE 6w x en y geruil

ABOVE	VOLUME	FE	TONNES	FILLVOL	TONNES	VOIDVOL	TON
50	2518137	60.86	11161008	69.1	11161008	4.82	11161
55	2205469	61.88	9928706	68.88	9928706	5.04	9928
57	2039031	62.32	9229046	68.71	9229046	5.21	9229
60	1626829	63.23	7442485	68.17	7442486	5.75	7442
62.5	1184724	63.88	5443163	67.48	5443163	6.44	5443
65	134141	65.57	616898	65.6	616898	8.32	616

APPENDIX B – GEOLOGICAL DEPOSIT EVALUATION RESULTS

KWAGGASHOEK-EAST:	**GRADE TONNAGE CURVE** **EVALUATION RESULTS**
DONKERPOORT-NECK:	**GRADE TONNAGE CURVE** **EVALUATION RESULTS**
DONKERPOORT-WEST:	**GRADE TONNAGE CURVE** **EVALUATION RESULTS**
BUFFELSHOEK-WEST:	**GRADE TONNAGE CURVE** **EVALUATION RESULTS**

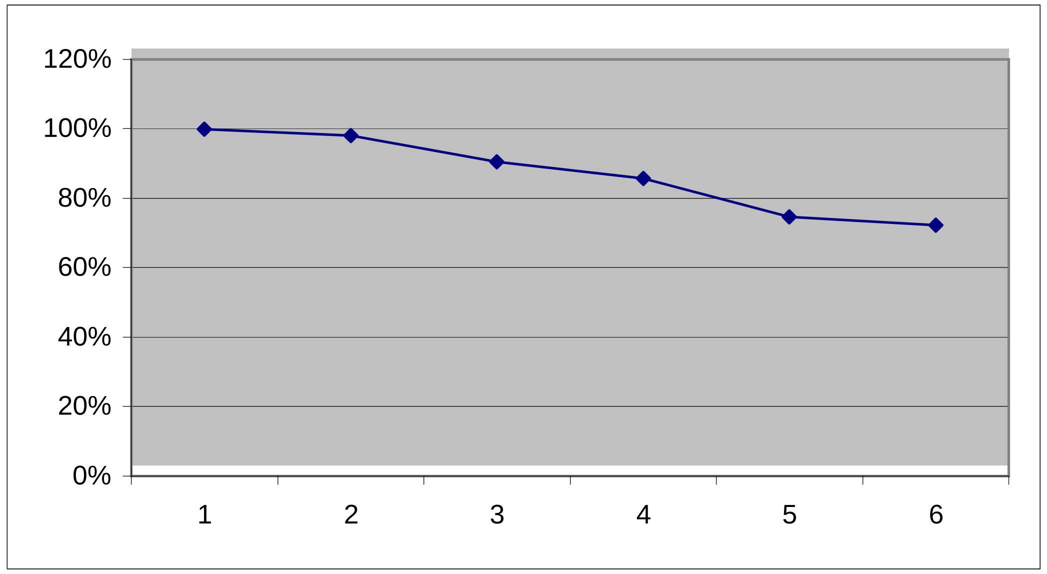

Kwaggashoek-east
Reserve tonnage
7200000
6900000
6600000
6300000
6000000
5700000
5400000
5100000
4800000
4500000
4200000
3900000
3600000
3300000
3000000
2700000
2400000
2100000
1800000
1500000
1200000
900000
600000
300000
0
% Fe Product quality
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
61
60.5
60
59.5
59
58.5
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
% Fe Cut off grade
TONNES - 6m
TONNES - 9m
TONNES - 3m
TONNES - 12m
TONNES - 15m
TONNES - 1m
%FE - 6m
%FE - 9m
%FE - 3m
%FE - 12m
%FE - 15m
%FE - 1m

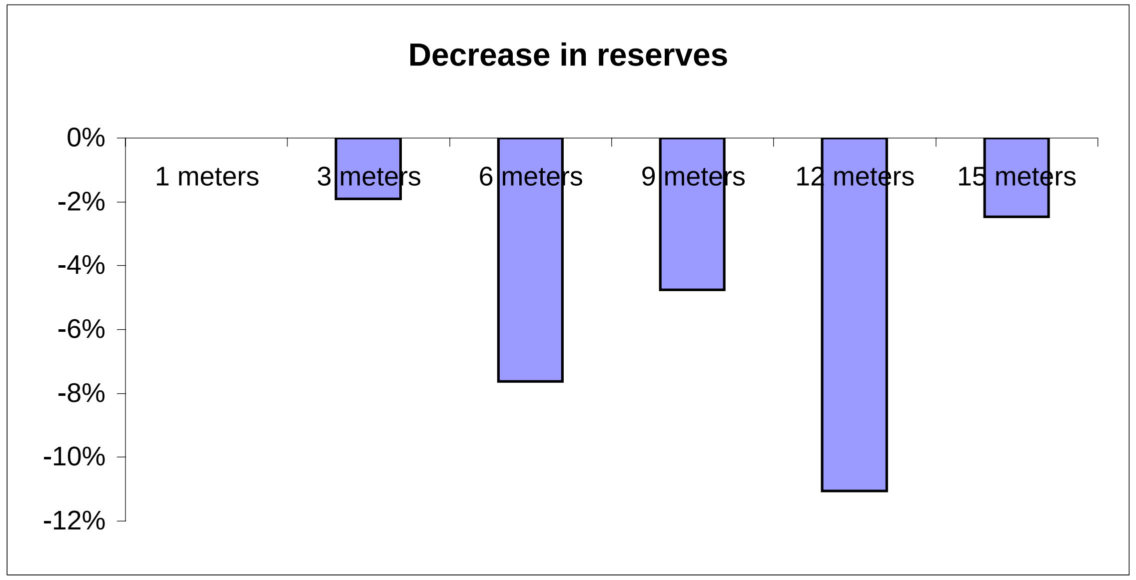
Kwaggashoek-East

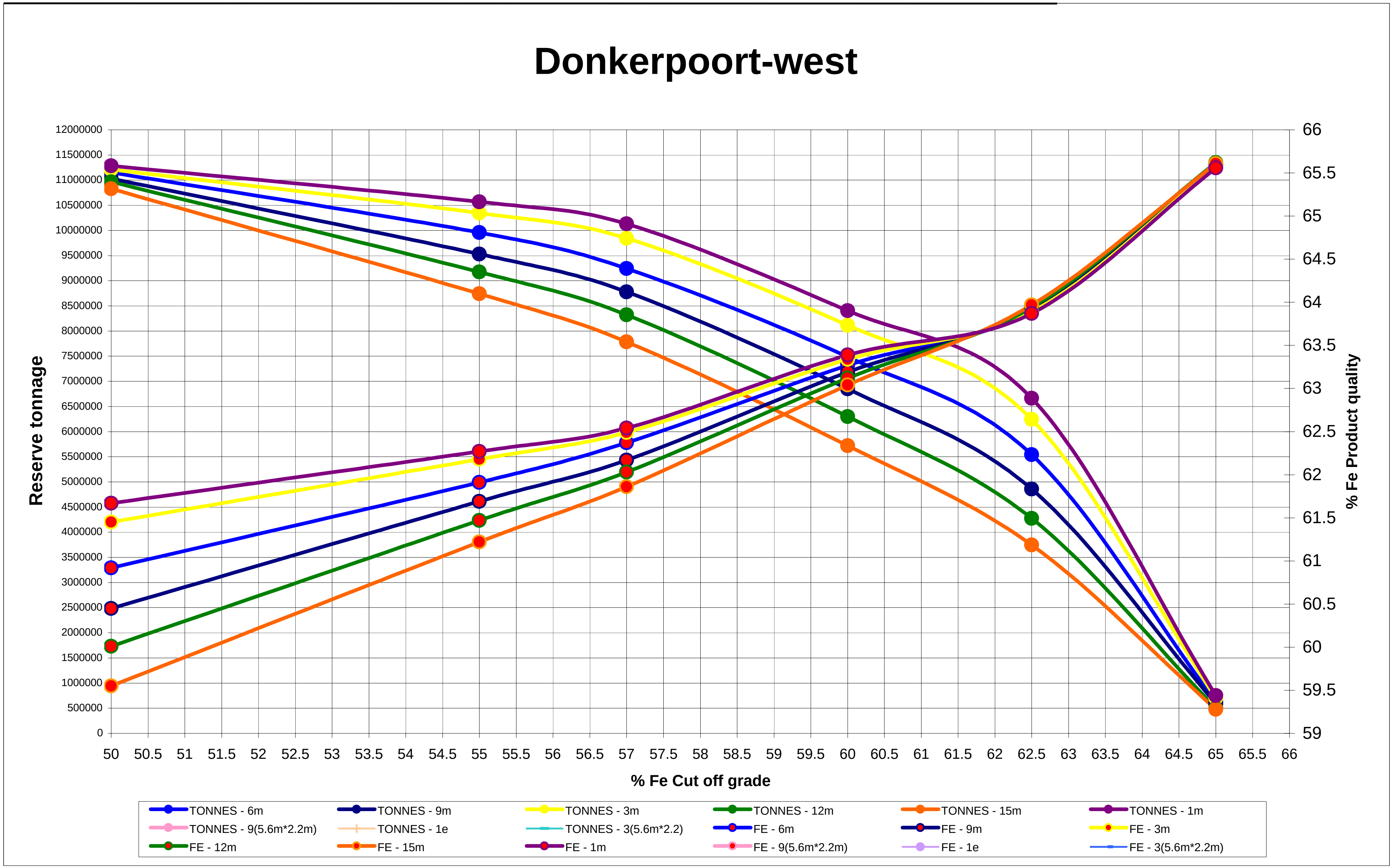
		Ore	Low Grade	Totaal tons
In situ		**5,239,073**	**572,849**	**49,024,858**
		Total Ore	**% change**	**Waste**
1 meters		5250000	100%	43,774,858
3 meters		5150000	98%	43,874,858
6 meters		4750000	90%	44,274,858
9 meters		4500000	86%	44,524,858
12 meters		3920000	75%	45,104,858
15 meters		3790000	72%	45,234,858

%Lae
10.9%

0%
-1.9%
-7.6%
-4.8%
-11.0%
-2.5%





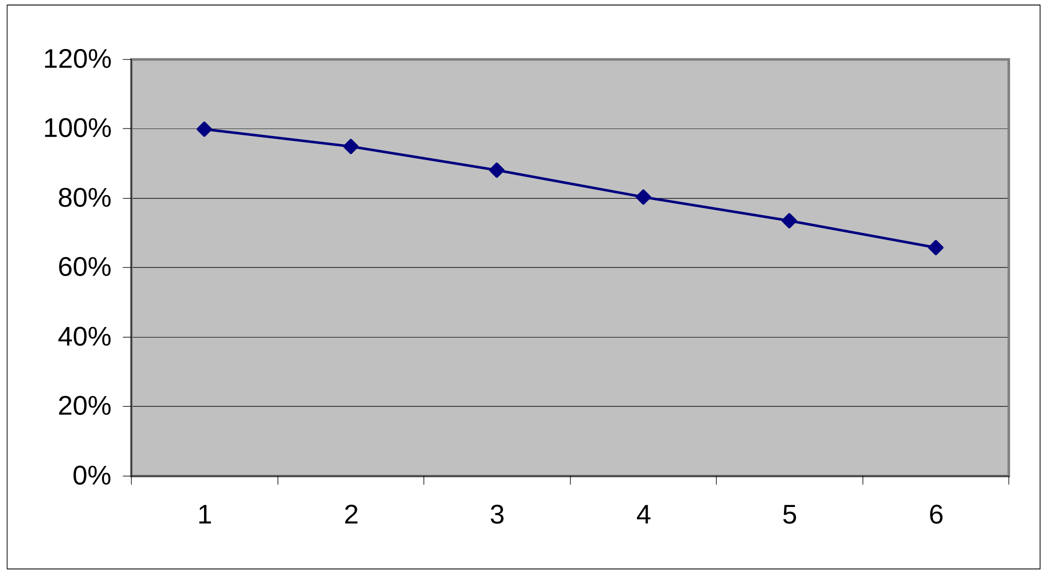

Donkerpoort-west
Reserve tonnage
0
500000
1000000
1500000
2000000
2500000
3000000
3500000
4000000
4500000
5000000
5500000
6000000
6500000
7000000
7500000
8000000
8500000
9000000
9500000
10000000
10500000
11000000
11500000
12000000
% Fe Product quality
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
% Fe Cut off grade
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
TONNES - 6m
TONNES - 9m
TONNES - 3m
TONNES - 12m
TONNES - 15m
TONNES - 1m
TONNES - 9(5.6m*2.2m)
TONNES - 1e
TONNES - 3(5.6m*2.2)
FE - 6m
FE - 9m
FE - 3m
FE - 12m
FE - 15m
FE - 1m
FE - 9(5.6m*2.2m)
FE - 1e
FE - 3(5.6m*2.2m)

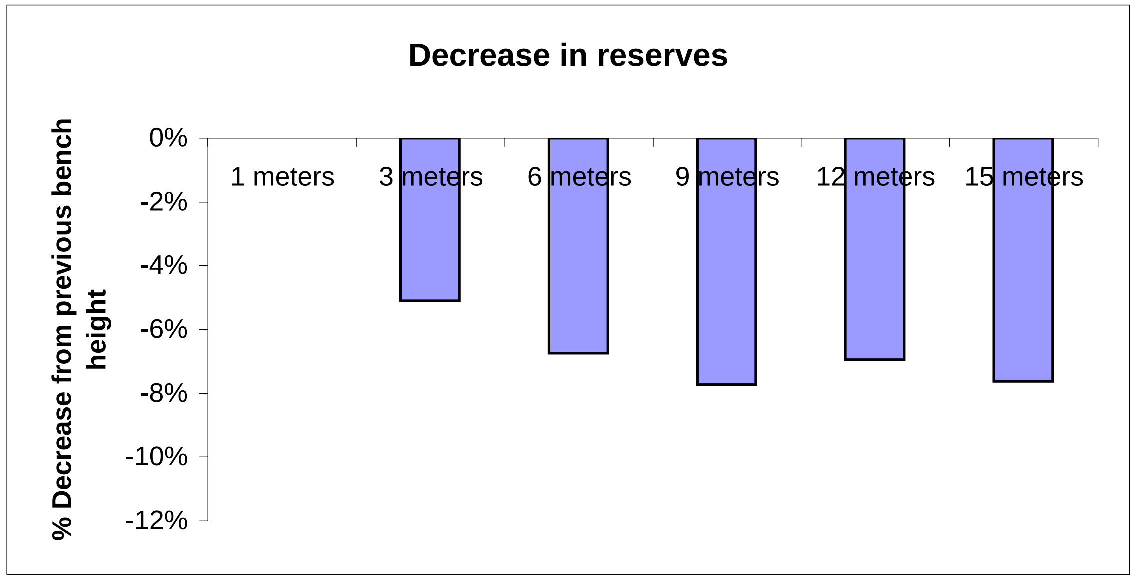
Donkerpoort-West

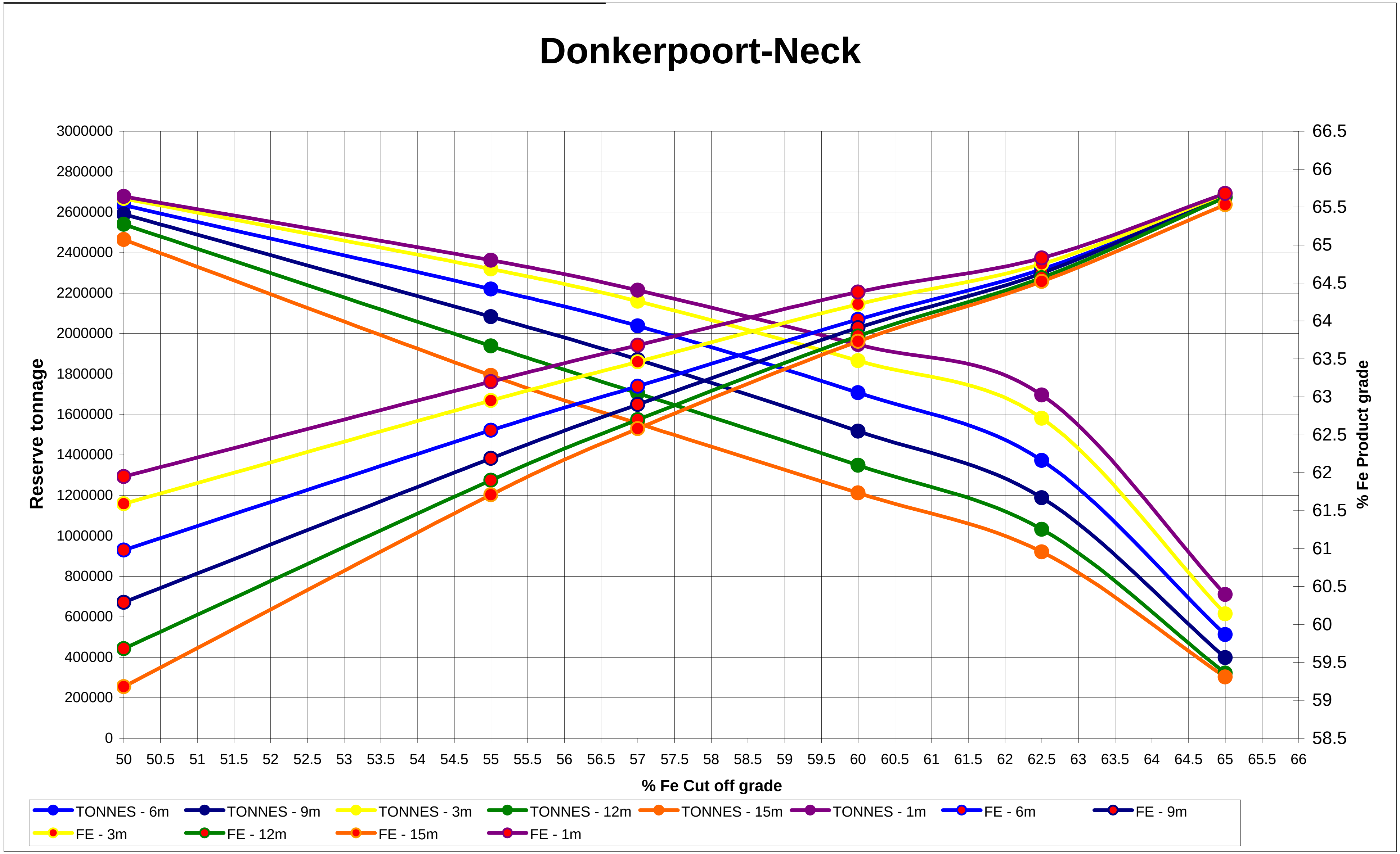
		Ore	Low Grade	Totaal tons
In situ		**10,373,000**	**1,029,548**	**99,458,000**
		Total Ore	% change	Waste
1 meters		10220000	100%	89,238,000
3 meters		9700000	95%	89,758,000
6 meters		9010000	88%	90,448,000
9 meters		8220000	80%	91,238,000
12 meters		7510000	73%	91,948,000
15 meters		6730000	66%	92,728,000

%Lae
9.9%

0%
-5.1%
-6.8%
-7.7%
-6.9%
-7.6%

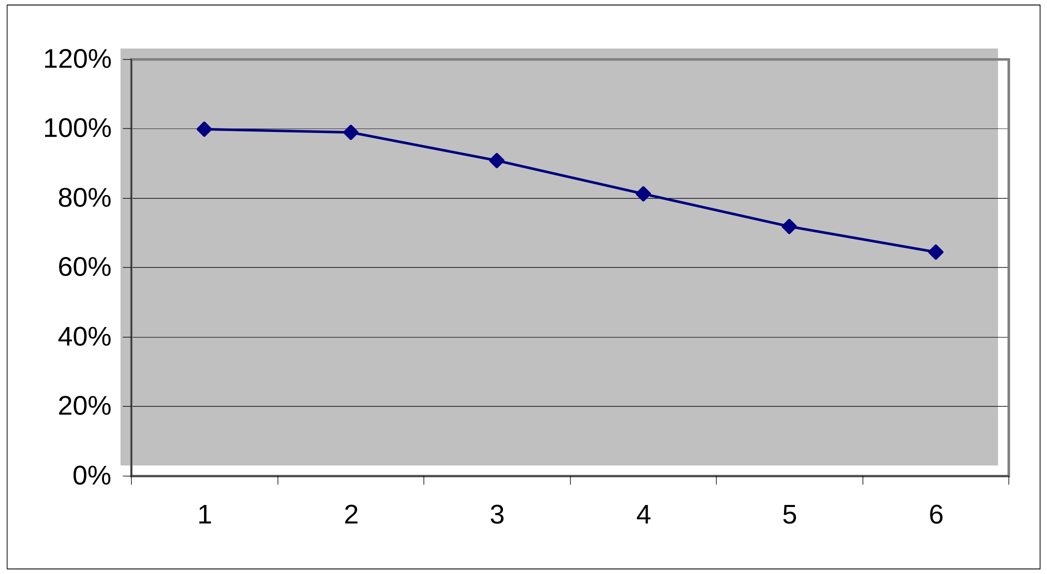


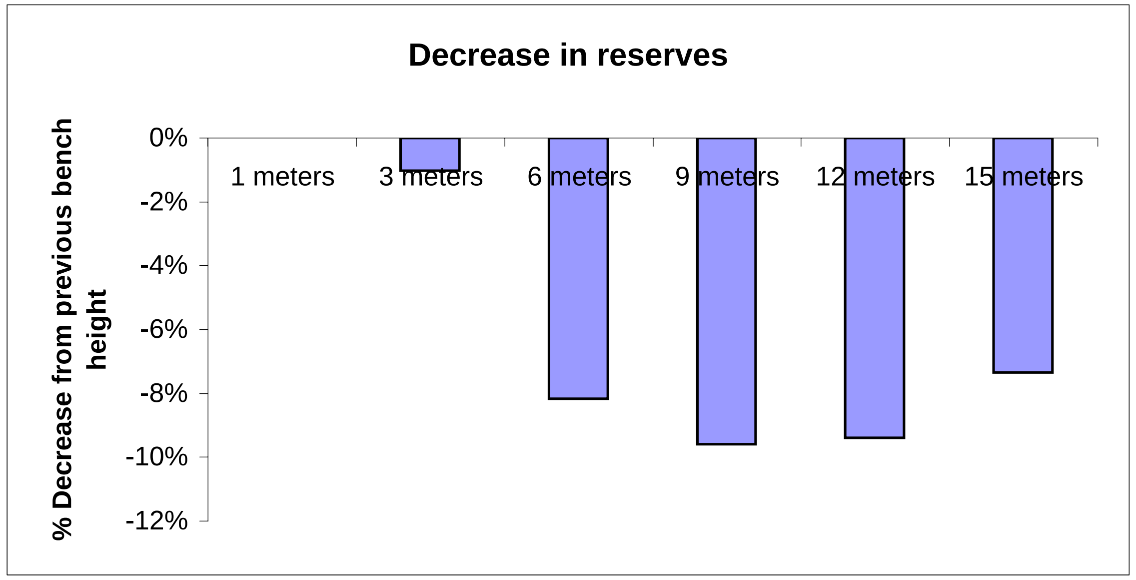

Decrease in reserves

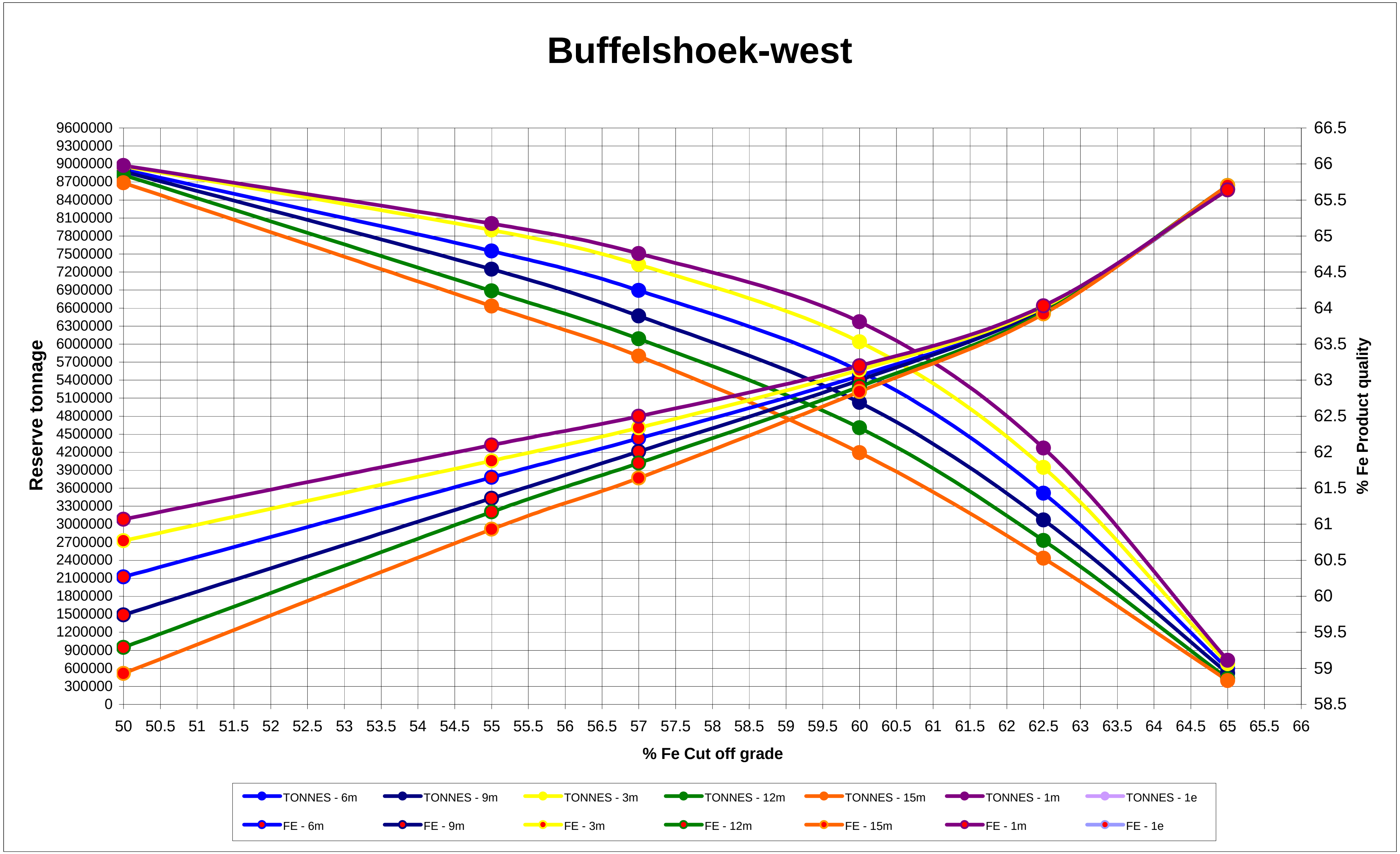

Donkerpoort-Neck
Reserve tonnage
3000000
2800000
2600000
2400000
2200000
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
% Fe Product grade
66.5
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
61
60.5
60
59.5
59
58.5
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
% Fe Cut off grade
TONNES - 6m
TONNES - 9m
TONNES - 3m
TONNES - 12m
TONNES - 15m
TONNES - 1m
FE - 6m
FE - 9m
FE - 3m
FE - 12m
FE - 15m
FE - 1m

Donkerpoort-Neck

		Ore	Low Grade	Totaal tons	%Lae	
In situ		**2,580,725**	**175,257**	**31,397,823**	6.8%	
		Total Ore	% change	Waste		
1 meters		2450000	100%	28,947,823		0%
3 meters		2425000	99%	28,972,823		-1.0%
6 meters		2225000	91%	29,172,823		-8.2%
9 meters		1990000	81%	29,407,823		-9.6%
12 meters		1760000	72%	29,637,823		-9.4%
15 meters		1580000	64%	29,817,823		-7.3%






Buffelshoek-west
Reserve tonnage
% Fe Product quality
% Fe Cut off grade
9600000
9300000
9000000
8700000
8400000
8100000
7800000
7500000
7200000
6900000
6600000
6300000
6000000
5700000
5400000
5100000
4800000
4500000
4200000
3900000
3600000
3300000
3000000
2700000
2400000
2100000
1800000
1500000
1200000
900000
600000
300000
0
66.5
66
65.5
65
64.5
64
63.5
63
62.5
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61.5
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60.5
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58.5
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51
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52
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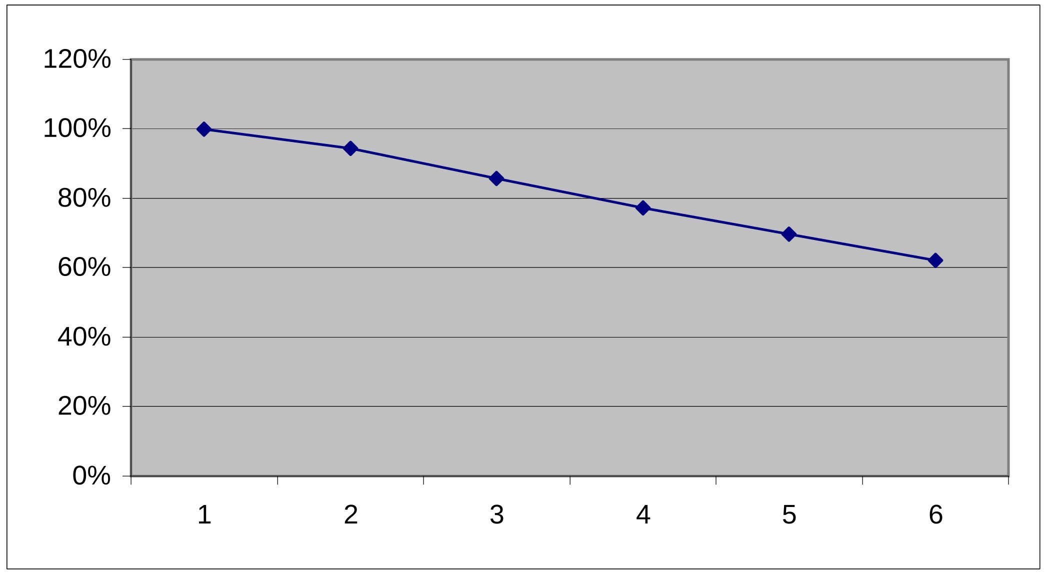
57
57.5
58
58.5
59
59.5
60
60.5
61
61.5
62
62.5
63
63.5
64
64.5
65
65.5
66
TONNES - 6m
TONNES - 9m
TONNES - 3m
TONNES - 12m
TONNES - 15m
TONNES - 1m
TONNES - 1e
FE - 6m
FE - 9m
FE - 3m
FE - 12m
FE - 15m
FE - 1m
FE - 1e

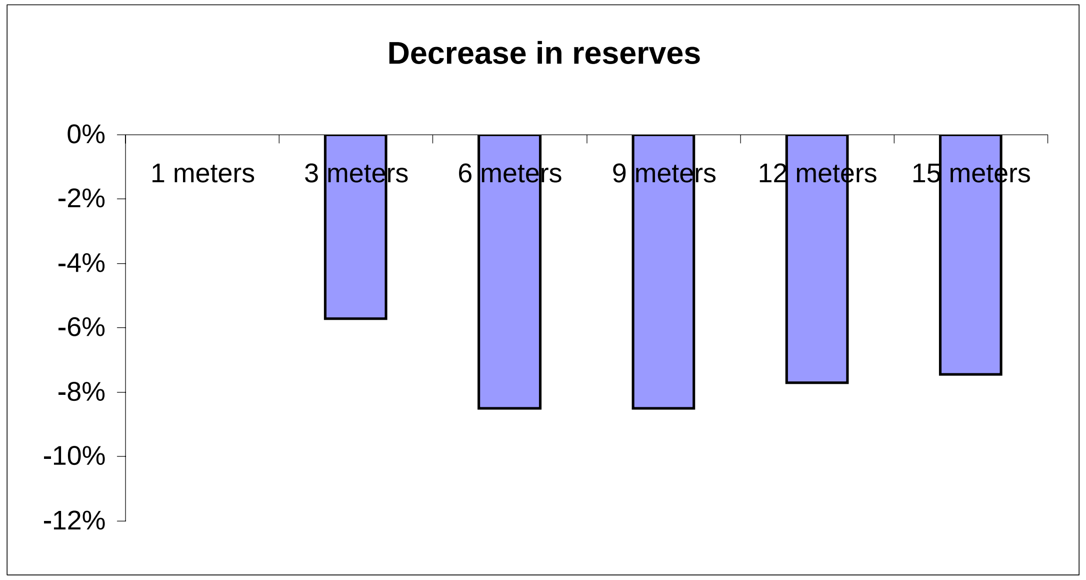
Buffelshoek-wes

		Ore	**Low Grade**	**Totaal tons**
In situ		**8,408,119**	**578,220**	**50,357,000**
		Total Ore	**% change**	**Waste**
1 meters		7530000	100%	42,827,000
3 meters		7100000	94%	43,257,000
6 meters		6460000	86%	43,897,000
9 meters		5820000	77%	44,537,000
12 meters		5240000	70%	45,117,000
15 meters		4680000	62%	45,677,000

%Lae
6.9%

0%
-5.7%
-8.5%
-8.5%
-7.7%
-7.4%





APPENDIX C – RESULTS OF PRODUCTIVITY SIMULATION

Equipment simulation results

Face Shovel	**16m3**	**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
% productive		50%	78%	100%	100%	80%
Prod rate		1318	2055	2635	2635	2108
Cycle time		60	38	30	30	37.5
bucket fill		100	100	100	100	100
Trucks/shovel		2	3	4	4	3

Rope Shovel	**18m3**	**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
% productive		44%	55%	89%	100%	100%
Prod rate		994	1245	2018	2267	2267
Cycle time		115	85	55	45	45
bucket fill		100	100	100	100	100
Trucks/shovel		2	2	3	3	3

Hydraulic Exc	**15m3**	**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
% productive		100%	90%	90%	80%	60%
Prod rate		2600	2122	2122	1948	1560
Cycle time		30	33	33.33333	37.5	50
bucket fill		100	100	100	100	100
Trucks/shovel		4	3	3	3	2

Wheel Loader	**16m3**	**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
% productive		75%	100%	100%	75%	75%
Prod rate		1284	1712	1712	1284	1284
Cycle time		50	45	45	50	50
bucket fill		100	100	100	100	100
Trucks/shovel		2	3	3	2	2

Results were obtained using TALPAC, by Runge (Australia) Pty Limted

APPENDIX D – ESCALATION RATES

Rope Shovel Model	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Macro Economic Indicators														
US PPI escalation	0.98	0.99	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.12	1.14	1.16
SA PPI escalation	1.09	1.17	1.24	1.31	1.39	1.47	1.56	1.65	1.75	1.86	1.97	2.09	2.21	2.35
R/$ exchange rates	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

APPENDIX E – DETAIL ECONOMIC EVALUATION

ROPE SHOVEL

HYDRAULIC FACE SHOVEL

HYDRAULIC EXCAVATOR

WHEEL LOADER

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Rope Shovel Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Macro Economic Indicators																						
US PPI escalation			0.98	0.99	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24		
SA PPI escalation			1.09	1.17	1.24	1.31	1.39	1.47	1.56	1.65	1.75	1.86	1.97	2.09	2.21	2.35	2.49	2.64	2.80	2.96		
R/$ exchange rates	100%		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00		
			9.54	9.05	9.22	9.42	9.60	9.59	9.59	9.59												
STATISTICS																						
Income per ton - Nominal terms	Ave. R/ton	137.73	214.59	217.29	220.12	223.12	225.57	228.04	230.73	233.44	236.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Income per ton - Real terms	Ave. R/ton	91.12	197.78	186.29	178.04	170.25	162.38	154.86	147.82	141.09	134.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Profit margin based on cash cost - Real	Ave. %	8%	29%	25%	22%	20%	17%	14%	10%	7%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Profit margin based on total cost - Real	Ave. %	-1%	17%	13%	10%	8%	5%	2%	-1%	-5%	-30%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Cash production cost - Total tons		8.41	8.68	8.66	8.55	8.44	8.34	8.27	8.21	8.15	8.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Cash production cost - Real terms	Ave. R/ton	135.79	140.05	139.81	138.01	136.27	134.63	133.55	132.51	131.53	135.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total Production cost - Nominal terms	R/ton	221.23	178.52	189.63	197.19	205.14	213.59	223.21	233.39	244.18	306.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total Production cost - Real Terms	Ave. R/ton	157.80	164.53	162.58	159.50	156.53	153.75	151.58	149.52	147.58	174.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total distribution cost - Nominal	Ave. R/ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total distribution cost - Real	Ave. R/ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Production Schedule	100%				100%	100%	100%	100%	100%													
Waste (Over-burden)	t	213,456,000	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	9,922,269	0	0	0	0	0	0	0	0	0		
Stripping Ratio	Ave.	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	0.0	0.0	0.0	0.0	0.0		
R.O.M Tonnage's	t	1,161,897	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	780,053	0	0	0	0	0	0	0	0	0		
Final Yield	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	0%	0%	0%	0%	0%		
Final product produced	t	14,263,962	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	663,045	0	0	0	0	0	0	0	0	0		
Closing stock calculation																						
Opening stock	t	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Production	t	14,263,962	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	663,045	-	-	-	-	-	-	-	-	-		
Total product sold	t	-14,263,962	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(663,045)	-	-	-	-	-	-	-	-	-		
- Market	t	-14,263,962	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(663,045)	-	-	-	-	-	-	-	-	-		
	t	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Closing stock	t	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Stock value per ton	R/ton	0	178.52	189.63	197.19	205.14	213.59	223.21	233.39	244.18	306.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Sales Schedule	100%																					
Sales Price																						
- Market	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
Revenue																						
- Market	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Gross Revenue	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
LESS : Distribution Cost	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Sales	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
Distribution cost schedule	100%																					
Export via RBCT	100%																					
- Road	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost RBCT																						
- Road	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Export via BMA (Durban)	100%																					
- Road	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost BMA (Durban)	R																					
- Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total distribution cost	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total :																						
- Road	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Cost of Sales Schedule	100%																					
80% Variable cost	100%	2,588,177,246	251,832,077	270,252,019	282,788,498	295,964,645	309,960,558	325,903,075	342,768,860	360,657,781	148,049,732	0	0	0	0	0	0	0	0	0		
- Mine		2,263,347,404	220,225,828	236,333,971	247,297,056	258,819,527	271,058,880	285,000,527	299,749,567	315,393,334	129,468,713	0	0	0	0	0	0	0	0	0		
- Plant handling cost - discard		5,066,670	492,992	529,051	553,593	579,387	606,785	637,995	671,011	706,031	289,825	0	0	0	0	0	0	0	0	0		
- Plant opex		315,259,465	30,675,042	32,918,730	34,445,767	36,050,721	37,755,529	39,697,447	41,751,827	43,930,832	18,033,571	0	0	0	0	0	0	0	0	0		
- Laboratory cost		4,503,707	438,215	470,268	492,082	515,010	539,365	567,106	596,455	627,583	257,622	0	0	0	0	0	0	0	0	0		
- Royalties		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
80% Fixed cost	100%	72,858,905	6,507,052	6,983,002	7,306,930	7,647,387	8,009,025	8,420,962	8,856,754	9,318,983	9,808,808	0	0	0	0	0	0	0	0	0		
- Mine		72,858,905	6,507,052	6,983,002	7,306,930	7,647,387	8,009,025	8,420,962	8,856,754	9,318,983	9,808,808	0	0	0	0	0	0	0	0	0		
- Plant		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Maintenance		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rehabilitation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Outside services		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Head Office costs (fixed)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Other costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total Production cost		2,661,036,151	258,339,129	277,235,021	290,095,429	303,612,032	317,969,584	334,324,037	351,625,614	369,976,764	157,858,540	0	0	0	0	0	0	0	0	0		
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total Cost of Sales		2,661,036,151	258,339,129	277,235,021	290,095,429	303,612,032	317,969,584	334,324,037	351,625,614	369,976,764	157,858,540	0	0	0	0	0	0	0	0	0		
EBITDA		543,809,895	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	-1,140,128	0	0	0	0	0	0	0	0	0		
CAPEX Schedule																						
80% SA R related Capex	100%	322,028,000	322,028,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
100% SA R related Land & Buildings	100%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20% US$ related Capex	100%	84,388,889	84,388,889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total capital		406,416,889	406,416,889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Working Capital		Opening Bal																				
Trade Debtors	365	-	29,985,748	30,362,959	30,758,484	31,177,164	31,520,121	31,865,170	32,241,389	32,620,003	12,880,965	0	0	0	0	0	0	0	0	0		
Stock - Coal		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Capital Creditors		-	(33,404,128)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Trade Creditors		-	(21,233,353)	(22,786,440)	(23,843,460)	(24,954,414)	(26,134,486)	(27,478,688)	(28,900,735)	(30,409,049)	(12,974,675)	-	-	-	-	-	-	-	-	-		
Total Working Capital	($3,217,208.07)	-	(24,651,733)	7,576,519	6,915,024	6,222,750	5,385,635	4,386,482	3,340,654	2,210,954	(93,709)	-	-	-	-	-	-	-	-	-		
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Change in total working capital		0	24,651,733	(32,228,252)	661,494	692,274	837,115	999,153	1,045,828	1,129,700	2,304,663	(93,709)	-	-	-	-	-	-	-	-		
Taxation before financial items		46,503,814	-	-	-	-	-	5,285,913	21,296,571	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-		
Change to Cash ("Petty Cash")		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$10,962,366.96		-246,575	-138,904,457	-41,737,114	36,248,235	43,807,019	58,470,951	79,596,245	56,344,652	58,302,157	56,844,013	56,223,025	50,604,335	84,278,224	2,690,518	-182,717	0	0			

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Rope Shovel Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Stand alone cash flow	($50,664,787.93)	90,889,191	-275,277,685	59,952,726	84,794,291	76,402,400	66,362,342	49,082,101	20,393,881	15,836,254	-6,905,447	248,329	0	0	0	0	0	0	0	0	0	0
Cummulative cash flow		0	-275,277,685	-215,324,959	-130,530,668	-54,128,269	12,234,074	61,316,174	81,710,055	97,546,309	90,640,862	90,889,191	90,889,191	90,889,191	90,889,191	90,889,191	90,889,191	90,889,191	90,889,191			
Interest (payable)/received		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Loan repayment		-																				
Investment Income received		-																				
Change in taxation due to interest charge		5,285,913	0	0	0	0	0	0	0	-10,724,745	3,817,271	4,123,405	8,412,021	-342,038	0	0	0	0	0	0		
Dividends and STC paid		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Cash Flow after financing		96,175,104	-275,277,685	59,952,726	84,794,291	76,402,400	66,362,342	49,082,101	20,393,881	5,111,509	-3,088,177	4,371,734	8,412,021	-342,038	0	0	0	0	0	0		
		0																				

Depreciation Schedule

ACCOUNTING DEPRECIATION

Period of depreciation of new assets 9.00
Historical per - P & M 9
Historical per - Buildings 9
Commence depreciation 2005
Life of mine (from commence date) 9

10

		TOTAL DEPR	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	
Opening Bal - Plant & machinery	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	
2004	406,416,889	406,416,889	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	0.00
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	0.00
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.00
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	0.00
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0.00
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0.00
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.00
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.00
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.00
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.00
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	-	0.00
2018	0	0															-	-	-	-	-	-	-	-	-	-	-	0.00
2019	0	0																-	-	-	-	-	-	-	-	-	-	0.00
2020	0	0																	-	-	-	-	-	-	-	-	-	0.00
2021	0	0																		-	-	-	-	-	-	-	-	0.00
																					-	-	-	-	-	-	-	
	406,416,889	406,416,889	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	45,157,432	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Check	0.00																										

TAX DEPRECIATION

Period of depreciation of new assets 1
Historical per - P & M -
Historical tax value -

		TOTAL DEPR	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Opening Bal - Plant & machinery		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
2004	406,416,889	406,416,889	406,416,889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#######
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	1	-
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	-
2018	0	0															-	-	-	-	-	-	-	-	-	-	1	-
2019	0	0																-	-	-	-	-	-	-	-	-	1	-
2020	0	0																	-	-	-	-	-	-	-	-	1	-
2021	0	0																		-	-	-	-	-	-	-	1	-
2022	0	0																			-	-	-	-	-	-	1	-
2023	0	0																				-	-	-	-	-	1	-
2024	0	0																					-	-	-	-	1	-
2025	0	0																						-	-	-	1	-
2026	0	0																							-	-	1	-
2027	0	0																								-	1	
2028	0	0																										
	406,416,889	406,416,889	406,416,889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Check	-																										

Taxation Schedule

RING FENCED MINE

Tax rate	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
STC Rate	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%
TFreceived - (Tax Factor) to be applied	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
TFpaid - (Tax Factor) to be applied	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%

TAX CALCULATION - Income Statement

OPERATING PROFIT (excl depr)	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	-1,140,128	0	0	0	0	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LESS DEPRECIATION	-45,157,432	-45,157,432	-45,157,432	-45,157,432	-45,157,432	-45,157,432	-45,157,432	-45,157,432	-45,157,432	0	0	0	0	0	0	0	0	0	0	0
TOTAL	61,330,039	47,023,546	38,975,364	30,552,693	20,367,795	8,211,428	-4,512,808	-18,257,491	-46,297,560	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	61,330,039	47,023,546	38,975,364	30,552,693	20,367,795	8,211,428	-4,512,808	-18,257,491	-46,297,560	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - FINANCIAL : (Dr) / Cr.	18,399,012	14,107,064	11,692,609	9,165,808	6,110,339	2,463,428	(1,353,842)	(5,477,247)	(13,889,268)	-	-	-	-	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax paid

OPERATING PROFIT (excl depr)	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	-1,140,128	0	0	0	0	0	0	0	0	0	0	0
Profit available for Unredeemed capital	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit /loss before Wear and Tear	106,487,471	-207,748,440	-123,615,644	-47,905,519	17,619,709	53,368,860	40,644,624	26,899,941	-	-	-	-	-	-	-	-	-	-	-	-
LESS Wear and Tear	-406,416,889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	0	0	0	17,619,709	53,368,860	40,644,624	26,899,941	-1,140,128	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - BEFORE INTEREST	-	-	-	-	5,285,913	16,010,658	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax afteinter.

OPERATING PROFIT (excl depr)	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	(1,140,128)	-	-	-	-	-	-	-	-	-	-	-
INTEREST RECEIVED /(PAYABLE)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit available for Unredeemed capital	106,487,471	92,180,978	84,132,796	75,710,125	65,525,227	53,368,860	40,644,624	26,899,941	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit available for Wear and Tear	106,487,471	-207,748,440	-123,615,644	-47,905,519	17,619,709	53,368,860	40,644,624	26,899,941	-	-	-	-	-	-	-	-	-	-	-	-
LESS Wear and Tear	-406,416,889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-299,929,418	-207,748,440	-123,615,644	-47,905,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	0	0	0	17,619,709	53,368,860	40,644,624	26,899,941	-1,140,128	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - AFTER INTEREST	-	-	-	-	5,285,913	16,010,658	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-	-	-	-

TAXATION CASHFLOW - before Interest

First and second payment		-	-	-	-	-	5,285,913	16,010,658	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-	-
Third payment		-	-	-	-	5,285,913	16,010,658	6,907,475	(7,940,676)	(8,412,021)	342,038	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	5,285,913	21,296,571	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-	-	-
Change in Taxation credit	-	-	-	-	(5,285,913)	(10,724,745)	9,103,183	4,123,405	8,412,021	(342,038)	-	-	-	-	-	-	-	-	-	-

TAXATION CASHFLOW - AfteInterest

First and second payment	-	-	-	-	-	-	5,285,913	16,010,658	12,193,387	8,069,982	(342,038)	-	-	-	-	-	-	-	-	-
Third payment		-	-	-	-	5,285,913	16,010,658	6,907,475	(7,940,676)	(12,535,426)	(8,069,982)	342,038	-	-	-	-	-	-	-	-
	-	-	-	-	-	5,285,913	21,296,571	22,918,133	4,252,712	(4,465,443)	(8,412,021)	342,038	-	-	-	-	-	-	-	-

University of Pretoria etd – Swanepoel, W (2003)

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Rope Shovel Model			**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Change in Taxation credit			-	-	-	-	(5,285,913)	(10,724,745)	9,103,183	14,848,150	4,594,750	(4,465,443)	(8,412,021)	342,038	-	-	-	-	-	-	-	-
Change to Deferred Taxation			18,399,012	14,107,064	11,692,609	9,165,808	824,426	-13,547,230	-13,547,230	-13,547,230	-13,547,230	-	-	-	-	-	-	-	-	-	-	-
STC TAXATION	**Capitalise=0 Cash=1**																					
Opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation Paid			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creditor STC			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change to STC Balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVIDEND / SHAREHOLDERS ACCOUNT	**Capitalise=0 Cash=1**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dividend Rate			33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Opening balance Shareholders Account			-	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends capitilized for the period			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Share Holder's Loan Balance			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends to be paid out			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends paid in cash			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closing balance cash dividends			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
REPAYMENT OF INTERGROUP LOAN																						
Interest payable on Loan			15.0%	12.6%	11.1%	10.5%	9.6%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	0.0%	0.0%
Interest receivable on Loan			12.0%	9.6%	8.1%	7.5%	6.6%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	0.0%	0.0%
Balance brought forward		-	**-**	**(275,277,685)**	**(215,324,959)**	**(130,530,668)**	**(54,128,269)**	**12,234,074**	**61,316,174**	**81,710,055**	**86,821,564**	**83,733,387**	**88,105,122**	**96,517,142**	**96,175,104**	**96,175,104**	**96,175,104**	**96,175,104**	**96,175,104**	**96,175,104**	**96,175,104**	**96,175,104**
Amount drawn		-	-275,277,685	59,952,726	84,794,291	76,402,400	66,362,342	49,082,101	20,393,881	15,836,254	-6,905,447	248,329	-	-	-	-	-	-	-	-	-	-
Balance before interest		-	(275,277,685)	(215,324,959)	(130,530,668)	(54,128,269)	12,234,074	61,316,174	81,710,055	97,546,309	79,916,117	83,981,717	88,105,122	96,517,142	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104
Amount (paid)/received - Interest		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	(275,277,685)	(215,324,959)	(130,530,668)	(54,128,269)	12,234,074	61,316,174	81,710,055	97,546,309	79,916,117	83,981,717	88,105,122	96,517,142	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104
Taxation movement - Interest		5,285,913	-	-	-	-	-	-	-	(10,724,745)	3,817,271	4,123,405	8,412,021	(342,038)	-	-	-	-	-	-	-	-
Balance at end of period		5,285,913	(275,277,685)	(215,324,959)	(130,530,668)	(54,128,269)	12,234,074	61,316,174	81,710,055	86,821,564	83,733,387	88,105,122	96,517,142	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104
		(90,889,191)																				
Average Cashflow			-137,638,843	-245,301,322	-172,927,814	-92,329,468	-20,947,097	36,775,124	71,513,115	89,628,182	83,368,840	83,857,552	88,105,122	96,517,142	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104	96,175,104
Net cashflow (Interest-taxation)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taxation Portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DCF VALUATION

VALUATION BEFORE FINANCING

Discount Rate	NPV - R 'M	IRR
10.0%	-0.9	
12.0%	260.3	9.9%
14.0%	-24.4	

81.39959387
88.6733183

VALUATION AFTER FINANCING
AND DIVIDENDS

Discount Rate	NPV - R 'M	IRR
#REF!	#REF!	
#REF!	#REF!	

CASH FLOW IN US$-TERMS	US$																				
		#REF!	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**

VALUATION BEFORE FINANCING

Discount Rate	NPV - US$ 'M	IRR
4.0%	#REF!	
6.0%	#REF!	

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Face Shovel Model			**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Macro Economic Indicators																						
US PPI escalation			0.98	0.99	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24		
SA PPI escalation			1.09	1.17	1.24	1.31	1.39	1.47	1.56	1.65	1.75	1.86	1.97	2.09	2.21	2.35	2.49	2.64	2.80	2.96		
R/$ exchange rates	**100%**		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00		
			9.54	9.05	9.22	9.42	9.60	9.59	9.59	9.59												
STATISTICS																						
Income per ton - Nominal terms	Ave. **R/ton**	235.54	**214.59**	**217.29**	**220.12**	**223.12**	**225.57**	**228.04**	**230.73**	**233.44**	**236.36**	**239.43**	**242.56**	**246.10**	**250.07**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Income per ton - Real terms	Ave. **R/ton**	139.38	**197.78**	**186.29**	**178.04**	**170.25**	**162.38**	**154.86**	**147.82**	**141.09**	**134.77**	**128.80**	**123.09**	**117.82**	**112.94**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Profit margin based on cash cost - Real	Ave. **%**	34%	**49%**	**46%**	**44%**	**43%**	**40%**	**38%**	**36%**	**33%**	**30%**	**30%**	**27%**	**25%**	**22%**	**0%**	**0%**	**0%**	**0%**	**0%**		
Profit margin based on total cost - Real	Ave. **%**	27%	**44%**	**41%**	**39%**	**38%**	**36%**	**33%**	**31%**	**28%**	**26%**	**26%**	**23%**	**20%**	**-2%**	**0%**	**0%**	**0%**	**0%**	**0%**		
Cash production cost - Total tons		8.51	**9.04**	**9.03**	**8.91**	**8.80**	**8.69**	**8.62**	**8.55**	**8.49**	**8.43**	**8.08**	**8.03**	**7.98**	**7.94**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Cash production cost - Real terms	Ave. **R/ton**	94.58	**100.51**	**100.34**	**99.05**	**97.80**	**96.63**	**95.85**	**95.10**	**94.40**	**93.74**	**89.84**	**89.27**	**88.75**	**88.26**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Total Production cost - Nominal terms	**R/ton**	164.61	**120.32**	**128.29**	**133.72**	**139.43**	**145.49**	**152.39**	**159.70**	**167.44**	**175.65**	**178.27**	**187.17**	**196.64**	**255.46**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Total Production cost - Real Terms	Ave. **R/ton**	103.67	**110.89**	**109.99**	**108.16**	**106.39**	**104.73**	**103.49**	**102.31**	**101.20**	**100.16**	**95.89**	**94.98**	**94.14**	**115.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Total distribution cost - Nominal	Ave. **R/ton**	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Total distribution cost - Real	Ave. **R/ton**	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Production Schedule	**100%**				**100%**	**100%**	**100%**	**100%**	**100%**													
Waste (Over-burden)	**t**	205,861,000	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	3,167,092	0	0	0	0	0		
Stripping Ratio	Ave.	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.0	0.0	0.0	0.0	0.0		
R.O.M Tonnage's	**t**	1,851,304	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	374,804	0	0	0	0	0		
Final Yield	**%**		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	0%	0%	0%	0%	0%		
Final product produced	**t**	20,707,911	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**318,583**	**0**	**0**	**0**	**0**	**0**		
Closing stock calculation																						
Opening stock	**t**	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Production	**t**	20,707,911	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	318,583	-	-	-	-	-		
Total product sold	**t**	-20,707,911	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(318,583)**	**-**	**-**	**-**	**-**	**-**		
- Market	**t**	-20,707,911	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(318,583)	-	-	-	-	-		
	t	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Closing stock	**t**	-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		
Stock value per ton	**R/ton**	0	**120.32**	**128.29**	**133.72**	**139.43**	**145.49**	**152.39**	**159.70**	**167.44**	**175.65**	**178.27**	**187.17**	**196.64**	**255.46**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Sales Schedule	**100%**																					
Sales Price																						
- Market	**$/t**	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
Revenue																						
- Market	**R**	4,764,722,969	364,611,147	369,197,836	374,007,219	379,098,144	383,268,333	387,463,939	392,038,578	396,642,324	401,604,769	406,825,631	412,140,457	418,157,708	79,666,884	0	0	0	0	0		
	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Gross Revenue	**R**	4,764,722,969	364,611,147	369,197,836	374,007,219	379,098,144	383,268,333	387,463,939	392,038,578	396,642,324	401,604,769	406,825,631	412,140,457	418,157,708	79,666,884	0	0	0	0	0		
LESS : Distribution Cost	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Sales	**R**	4,764,722,969	**364,611,147**	**369,197,836**	**374,007,219**	**379,098,144**	**383,268,333**	**387,463,939**	**392,038,578**	**396,642,324**	**401,604,769**	**406,825,631**	**412,140,457**	**418,157,708**	**79,666,884**	**0**	**0**	**0**	**0**	**0**		
Distribution cost schedule	**100%**																					
Export via RBCT	**100%**																					
- Road	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost RBCT																						
- Road	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Export via BMA (Durban)	**100%**																					
- Road	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost BMA (Durban)	**R**																					
- Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total distribution cost	**R**	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
Total :																						
- Road	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Cost of Sales Schedule	**100%**																					
80% Variable cost	**100%**	2,961,856,260	178,795,333	191,873,094	200,773,723	210,128,503	220,065,299	231,384,141	243,358,484	256,059,231	269,518,233	283,763,640	298,900,770	314,980,364	62,255,443	0	0	0	0	0		
- Mine		2,438,588,233	147,207,750	157,975,077	165,303,241	173,005,322	181,186,594	190,505,749	200,364,597	210,821,517	221,902,730	233,631,416	246,094,286	259,333,115	51,256,839	0	0	0	0	0		
- Plant handling cost - discard		8,161,893	492,701	528,739	553,266	579,044	606,427	637,618	670,615	705,614	742,703	781,958	823,671	867,981	171,555	0	0	0	0	0		
- Plant opex		507,851,117	30,656,927	32,899,289	34,425,425	36,029,431	37,733,232	39,674,003	41,727,169	43,904,888	46,212,619	48,655,191	51,250,661	54,007,729	10,674,555	0	0	0	0	0		
- Laboratory cost		7,255,016	437,956	469,990	491,792	514,706	539,046	566,771	596,102	627,213	660,180	695,074	732,152	771,539	152,494	0	0	0	0	0		
- Royalties		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
80% Fixed cost	**100%**	72,858,905	6,507,052	6,983,002	7,306,930	7,647,387	8,009,025	8,420,962	8,856,754	9,318,983	9,808,808	0	0	0	0	0	0	0	0	0		
- Mine		72,858,905	6,507,052	6,983,002	7,306,930	7,647,387	8,009,025	8,420,962	8,856,754	9,318,983	9,808,808	0	0	0	0	0	0	0	0	0		
- Plant		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Maintenance		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rehabilitation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Outside services		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Head Office costs (fixed)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Other costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total Production cost		3,034,715,165	**185,302,385**	**198,856,096**	**208,080,654**	**217,775,890**	**228,074,324**	**239,805,103**	**252,215,239**	**265,378,215**	**279,327,041**	**283,763,640**	**298,900,770**	**314,980,364**	**62,255,443**	**0**	**0**	**0**	**0**	**0**		
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total Cost of Sales		3,034,715,165	**185,302,385**	**198,856,096**	**208,080,654**	**217,775,890**	**228,074,324**	**239,805,103**	**252,215,239**	**265,378,215**	**279,327,041**	**283,763,640**	**298,900,770**	**314,980,364**	**62,255,443**	**0**	**0**	**0**	**0**	**0**		
EBITDA		1,730,007,804	**179,308,761**	**170,341,739**	**165,926,566**	**161,322,254**	**155,194,009**	**147,658,836**	**139,823,339**	**131,264,110**	**122,277,728**	**123,061,992**	**113,239,687**	**103,177,344**	**17,411,441**	**0**	**0**	**0**	**0**	**0**		
CAPEX Schedule																						
80% SA R related Capex	**100%**	197,036,000	197,036,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
100% SA R related Land & Buildings	**100%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20% US$ related Capex	**100%**	51,634,172	51,634,172	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total capital		248,670,172	**248,670,172**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
Working Capital		Opening Bal																				
Trade Debtors	**365**	-	29,968,039	30,345,028	30,740,319	31,158,752	31,501,507	31,846,351	32,222,349	32,600,739	33,008,611	33,437,723	33,874,558	34,369,127	6,547,963	0	0	0	0	0		
Stock - Coal		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Capital Creditors		-	(20,438,644)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Trade Creditors		-	(15,230,333)	(16,344,337)	(17,102,519)	(17,899,388)	(18,745,835)	(19,710,008)	(20,730,020)	(21,811,908)	(22,958,387)	(23,323,039)	(24,567,187)	(25,888,797)	(5,116,886)	-	-	-	-	-		
Total Working Capital	**$40,084,543.77**	-	**(5,700,938)**	**14,000,691**	**13,637,800**	**13,259,363**	**12,755,672**	**12,136,343**	**11,492,329**	**10,788,831**	**10,050,224**	**10,114,684**	**9,307,371**	**8,480,330**	**1,431,077**	**-**	**-**	**-**	**-**	**-**		
Change in stock value		0	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		
Change in total working capital		0	**5,700,938**	**(19,701,629)**	**362,891**	**378,437**	**503,691**	**619,329**	**644,013**	**703,498**	**738,607**	**(64,460)**	**807,313**	**827,042**	**7,049,252**	**1,431,077**	**-**	**-**	**-**	**-**		
Taxation before financial items		490,959,492	-	-	30,294,099	80,072,068	67,880,547	45,176,909	42,459,177	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-		
Change to Cash ("Petty Cash")		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$10,962,366.96		-246,575	-138,904,457	-41,737,114	36,248,235	43,807,019	58,470,951	79,596,245	56,344,652	58,302,157	56,844,013	56,223,025	50,604,335	84,278,224	2,690,518	-182,717	0	0			

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Face Shovel Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Stand alone cash flow	$335,218,445.61	990,378,140	-63,660,473	150,640,111	135,995,358	81,628,622	87,817,153	103,101,256	98,008,175	90,020,606	83,637,102	86,314,213	77,128,402	70,032,480	-6,492,510	-3,792,355	0	0	0	0	0	0
Cummulative cash flow		0	-63,660,473	86,979,638	222,974,996	304,603,618	392,420,771	495,522,027	593,530,202	683,550,809	767,187,911	853,502,124	930,630,526	1,000,663,005	994,170,495	990,378,140	990,378,140	990,378,140	990,378,140			
Interest (payable)/received		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Loan repayment		-																				
Investment Income received		-																				
Change in taxation due to interest charge		46,558,203	0	0	0	0	0	0	0	2,260,552	2,350,649	2,567,769	2,695,914	-235,279	2,946,692	3,018,703	25,729,771	5,223,432	0	0		
Dividends and STC paid		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Cash Flow after financing		1,036,936,343	-63,660,473	150,640,111	135,995,358	81,628,622	87,817,153	103,101,256	98,008,175	92,281,158	85,987,751	88,881,982	79,824,316	69,797,200	-3,545,818	-773,652	25,729,771	5,223,432	0	0		
		0																				

Depreciation Schedule

ACCOUNTING DEPRECIATION

Period of depreciation of new assets	13.00
Historical per - P & M	13
Historical per - Buildings	13
Commence depreciation	2005
Life of mine (from commence date)	13

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		TOTAL DEPR	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	
Opening Bal - Plant & machinery	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	
2004	248,670,172	248,670,172	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	-	-	-	-	-	-	-	-	-	-	-	13	0.00
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	0.00
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0.00
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	0.00
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	0.00
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	0.00
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.00
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	0.00
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0.00
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0.00
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.00
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.00
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	2	0.00
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	0.00
2018	0	0															-	-	-	-	-	-	-	-	-	-	-	0.00
2019	0	0																-	-	-	-	-	-	-	-	-	-	0.00
2020	0	0																	-	-	-	-	-	-	-	-	-	0.00
2021	0	0																		-	-	-	-	-	-	-	-	0.00
																					-	-	-	-	-	-	-	
	248,670,172	248,670,172	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	19,128,475	0	0	0	0	0	0	0	0	0	0	0		
	Check	0.00																										

TAX DEPRECIATION

Period of depreciation of new assets	1
Historical per - P & M	-
Historical tax value	-

		TOTAL DEPR	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Opening Bal - Plant & machinery		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
2004	248,670,172	248,670,172	248,670,172	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#######
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	1	-
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	-
2018	0	0															-	-	-	-	-	-	-	-	-	-	1	-
2019	0	0																-	-	-	-	-	-	-	-	-	1	-
2020	0	0																	-	-	-	-	-	-	-	-	1	-
2021	0	0																		-	-	-	-	-	-	-	1	-
2022	0	0																			-	-	-	-	-	-	1	-
2023	0	0																				-	-	-	-	-	1	-
2024	0	0																					-	-	-	-	1	-
2025	0	0																						-	-	-	1	-
2026	0	0																							-	-	1	-
2027	0	0																								-	1	
2028	0	0																										
	248,670,172	248,670,172	248,670,172	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Check	-																										

Taxation Schedule

RING FENCED MINE

Tax rate	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
STC Rate	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%
TFreceived - (Tax Factor) to be applied	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
TFpaid - (Tax Factor) to be applied	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%

TAX CALCULATION - Income Statement

OPERATING PROFIT (excl depr)	179,308,761	170,341,739	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LESS DEPRECIATION	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	-19,128,475	0	0	0	0	0	0	0
TOTAL	160,180,287	151,213,265	146,798,091	142,193,779	136,065,534	128,530,361	120,694,865	112,135,635	103,149,253	103,933,517	94,111,212	84,048,869	-1,717,034	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	160,180,287	151,213,265	146,798,091	142,193,779	136,065,534	128,530,361	120,694,865	112,135,635	103,149,253	103,933,517	94,111,212	84,048,869	-1,717,034	0	0	0	0	0	0	0
TAX PAYABLE - FINANCIAL : (Dr) / Cr.	48,054,086	45,363,979	44,039,427	42,658,134	40,819,660	38,559,108	36,208,459	33,640,690	30,944,776	31,180,055	28,233,364	25,214,661	(515,110)	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax paid

OPERATING PROFIT (excl depr)	179,308,761	170,341,739	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
Profit available for Unredeemed capital	179,308,761	170,341,739	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit /loss before Wear and Tear	179,308,761	100,980,329	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	-	-	-	-	-	-	-
LESS Wear and Tear	-248,670,172	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	100,980,329	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
TAX PAYABLE - BEFORE INTEREST	-	30,294,099	49,777,970	48,396,676	46,558,203	44,297,651	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax afteinter.

OPERATING PROFIT (excl depr)	179,308,761	170,341,739	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	-	-	-	-	-	-	-
INTEREST RECEIVED /(PAYABLE)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit available for Unredeemed capital	179,308,761	170,341,739	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit available for Wear and Tear	179,308,761	100,980,329	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	-	-	-	-	-	-	-
LESS Wear and Tear	-248,670,172	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-69,361,411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	100,980,329	165,926,566	161,322,254	155,194,009	147,658,836	139,823,339	131,264,110	122,277,728	123,061,992	113,239,687	103,177,344	17,411,441	0	0	0	0	0	0	0
TAX PAYABLE - AFTER INTEREST	-	30,294,099	49,777,970	48,396,676	46,558,203	44,297,651	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-	-	-	-

TAXATION CASHFLOW - before Interest

First and second payment		-	-	30,294,099	49,777,970	48,396,676	46,558,203	44,297,651	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-	-
Third payment		-	30,294,099	49,777,970	18,102,577	(3,219,767)	(4,099,025)	(4,611,201)	(4,918,418)	(2,695,914)	235,279	(2,946,692)	(3,018,703)	(25,729,771)	(5,223,432)	-	-	-	-	-
	-	-	30,294,099	80,072,068	67,880,547	45,176,909	42,459,177	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-	-	-
Change in Taxation credit	-	(30,294,099)	(19,483,871)	31,675,392	21,322,345	879,258	512,176	2,567,769	2,695,914	(235,279)	2,946,692	3,018,703	25,729,771	5,223,432	-	-	-	-	-	-

TAXATION CASHFLOW - AfteInterest

First and second payment	-	-	-	30,294,099	49,777,970	48,396,676	46,558,203	44,297,651	41,947,002	39,379,233	36,683,318	36,918,598	33,971,906	30,953,203	5,223,432	-	-	-	-	-
Third payment		-	30,294,099	49,777,970	18,102,577	(3,219,767)	(4,099,025)	(4,611,201)	(4,918,418)	(5,263,683)	(2,460,635)	(2,711,413)	(5,965,394)	(28,748,474)	(30,953,203)	(5,223,432)	-	-	-	-
	-	-	30,294,099	80,072,068	67,880,547	45,176,909	42,459,177	39,686,450	37,028,584	34,115,550	34,222,683	34,207,185	28,006,512	2,204,729	(25,729,771)	(5,223,432)	-	-	-	-

"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Face Shovel Model		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Change in Taxation credit		-	(30,294,099)	(19,483,871)	31,675,392	21,322,345	879,258	512,176	307,217	345,265	(2,803,048)	250,777	3,253,982	22,783,079	2,204,729	(25,729,771)	(5,223,432)	-	-	-	-
Change to Deferred Taxation		48,054,086	15,069,881	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-5,738,542	-	-	-	-	-	-	-
STC TAXATION	**Capitalise=0 Cash=1**																				
Opening balance		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation Paid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creditor STC		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change to STC Balance		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVIDEND / SHAREHOLDERS ACCOUNT	**Capitalise=0 Cash=1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividend Rate		33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Opening balance Shareholders Account		-	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends capitilized for the period		#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Share Holder's Loan Balance		#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends opening balance		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends to be paid out		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends paid in cash		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closing balance cash dividends		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
REPAYMENT OF INTERGROUP LOAN																					
Interest payable on Loan		15.0%	12.6%	11.1%	10.5%	9.6%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	0.0%	0.0%
Interest receivable on Loan		12.0%	9.6%	8.1%	7.5%	6.6%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	0.0%	0.0%
Balance brought forward	-	**-**	**(63,660,473)**	**86,979,638**	**222,974,996**	**304,603,618**	**392,420,771**	**495,522,027**	**593,530,202**	**685,811,360**	**771,799,111**	**860,681,094**	**940,505,410**	**1,010,302,610**	**1,006,756,792**	**1,005,983,140**	**1,031,712,911**	**1,036,936,343**	**##########**	**###########**	**###########**
Amount drawn	-	-63,660,473	150,640,111	135,995,358	81,628,622	87,817,153	103,101,256	98,008,175	90,020,606	83,637,102	86,314,213	77,128,402	70,032,480	-6,492,510	-3,792,355	-	-	-	-	-	-
Balance before interest	-	(63,660,473)	86,979,638	222,974,996	304,603,618	392,420,771	495,522,027	593,530,202	683,550,809	769,448,462	858,113,325	937,809,495	1,010,537,889	1,003,810,100	1,002,964,437	1,005,983,140	1,031,712,911	1,036,936,343	##########	###########	###########
Amount (paid)/received - Interest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	(63,660,473)	86,979,638	222,974,996	304,603,618	392,420,771	495,522,027	593,530,202	683,550,809	769,448,462	858,113,325	937,809,495	1,010,537,889	1,003,810,100	1,002,964,437	1,005,983,140	1,031,712,911	1,036,936,343	##########	###########	###########
Taxation movement - Interest	46,558,203	-	-	-	-	-	-	-	2,260,552	2,350,649	2,567,769	2,695,914	(235,279)	2,946,692	3,018,703	25,729,771	5,223,432	-	-	-	-
Balance at end of period	46,558,203	(63,660,473)	86,979,638	222,974,996	304,603,618	392,420,771	495,522,027	593,530,202	685,811,360	771,799,111	860,681,094	940,505,410	1,010,302,610	1,006,756,792	1,005,983,140	1,031,712,911	1,036,936,343	1,036,936,343	##########	###########	###########
	(990,378,140)																				
Average Cashflow		-31,830,236	11,659,583	154,977,317	263,789,307	348,512,194	443,971,399	544,526,115	638,540,505	727,629,911	814,956,218	899,245,294	975,521,649	1,007,056,355	1,004,860,614	1,005,983,140	1,031,712,911	1,036,936,343	##########	###########	###########
Net cashflow (Interest-taxation)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest portion		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taxation Portion		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DCF VALUATION

	Discount Rate	NPV - R 'M	IRR	
VALUATION BEFORE FINANCING	10.0%	544.8		
	12.0%	613.0	221.7%	81.39959387
	14.0%	443.5		88.6733183

	Discount Rate	NPV - R 'M	IRR
VALUATION AFTER FINANCING AND DIVIDENDS	#REF!	#REF!	
	#REF!	#REF!	

CASH FLOW IN US$-TERMS	US$	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!

	Discount Rate	NPV - US$ 'M	IRR
VALUATION BEFORE FINANCING	4.0%	#REF!	
	6.0%	#REF!	

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Hydr Excav Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Macro Economic Indicators																						
US PPI escalation			0.98	0.99	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24		
SA PPI escalation			1.09	1.17	1.24	1.31	1.39	1.47	1.56	1.65	1.75	1.86	1.97	2.09	2.21	2.35	2.49	2.64	2.80	2.96		
R/$ exchange rates	100%		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00		
			9.54	9.05	9.22	9.42	9.60	9.59	9.59	9.59												
STATISTICS																						
Income per ton - Nominal terms	Ave. R/ton	137.73	214.59	217.29	220.12	223.12	225.57	228.04	230.73	233.44	236.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Income per ton - Real terms	Ave. R/ton	91.12	197.78	186.29	178.04	170.25	162.38	154.86	147.82	141.09	134.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Profit margin based on cash cost - Real	Ave. %	8%	29%	25%	22%	20%	17%	13%	10%	6%	-2%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Profit margin based on total cost - Real	Ave. %	2%	21%	17%	14%	12%	9%	6%	3%	-1%	-20%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Cash production cost - Total tons		8.46	8.73	8.71	8.60	8.49	8.39	8.32	8.26	8.20	8.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Cash production cost - Real terms	Ave. R/ton	136.59	140.85	140.60	138.80	137.04	135.40	134.31	133.26	132.28	136.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total Production cost - Nominal terms	R/ton	210.81	169.54	180.71	188.32	196.32	204.81	214.48	224.72	235.57	282.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total Production cost - Real Terms	Ave. R/ton	150.44	156.25	154.94	152.32	149.80	147.43	145.66	143.97	142.38	161.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total distribution cost - Nominal	Ave. R/ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total distribution cost - Real	Ave. R/ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Production Schedule	100%				100%	100%	100%	100%	100%													
Waste (Over-burden)	t	213,456,000	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	25,441,716	9,922,269	0	0	0	0	0	0	0	0	0		
Stripping Ratio	Ave.	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	0.0	0.0	0.0	0.0	0.0		
R.O.M Tonnage's	t	1,161,897	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	2,000,135	780,053	0	0	0	0	0	0	0	0	0		
Final Yield	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	0%	0%	0%	0%	0%		
Final product produced	t	14,263,962	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	663,045	0	0	0	0	0	0	0	0	0		
Closing stock calculation																						
Opening stock	t	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Production	t	14,263,962	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	1,700,115	663,045	-	-	-	-	-	-	-	-	-		
Total product sold	t	-14,263,962	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(663,045)	-	-	-	-	-	-	-	-	-		
- Market	t	-14,263,962	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(1,700,115)	(663,045)	-	-	-	-	-	-	-	-	-		
	t	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Closing stock	t	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Stock value per ton	R/ton	0	169.54	180.71	188.32	196.32	204.81	214.48	224.72	235.57	282.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Sales Schedule	100%																					
Sales Price																						
- Market	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00		
Revenue																						
- Market	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Gross Revenue	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
LESS : Distribution Cost	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Sales	R	3,204,846,045	364,826,600	369,415,999	374,228,225	379,322,158	383,494,811	387,692,897	392,270,238	396,876,705	156,718,412	0	0	0	0	0	0	0	0	0		
Distribution cost schedule	100%																					
Export via RBCT	100%																					
- Road	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost RBCT																						
- Road	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Export via BMA (Durban)	100%																					
- Road	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Distribution cost BMA (Durban)	R																					
- Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rail		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Port		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total distribution cost	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total :																						
- Road	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Rail	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
- Port	R/t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Cost of Sales Schedule	100%																					
80% Variable cost	100%	2,599,240,018	252,908,495	271,407,171	283,997,235	297,229,701	311,285,438	327,296,098	344,233,974	362,199,358	148,682,548	0	0	0	0	0	0	0	0	0		
- Mine		2,274,410,176	221,302,247	237,489,122	248,505,793	260,084,583	272,383,759	286,393,550	301,214,681	316,934,912	130,101,529	0	0	0	0	0	0	0	0	0		
- Plant handling cost - discard		5,066,670	492,992	529,051	553,593	579,387	606,785	637,995	671,011	706,031	289,825	0	0	0	0	0	0	0	0	0		
- Plant opex		315,259,465	30,675,042	32,918,730	34,445,767	36,050,721	37,755,529	39,697,447	41,751,827	43,930,832	18,033,571	0	0	0	0	0	0	0	0	0		
- Laboratory cost		4,503,707	438,215	470,268	492,082	515,010	539,365	567,106	596,455	627,583	257,622	0	0	0	0	0	0	0	0	0		
- Royalties		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
80% Fixed cost	100%	77,274,596	6,901,419	7,406,215	7,749,775	8,110,865	8,494,421	8,931,323	9,393,527	9,883,770	10,403,282	0	0	0	0	0	0	0	0	0		
- Mine		77,274,596	6,901,419	7,406,215	7,749,775	8,110,865	8,494,421	8,931,323	9,393,527	9,883,770	10,403,282	0	0	0	0	0	0	0	0	0		
- Plant		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Maintenance		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Rehabilitation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
- Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Outside services		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Head Office costs (fixed)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Other costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total Production cost		2,676,514,614	259,809,914	278,813,385	291,747,010	305,340,566	319,779,859	336,227,421	353,627,501	372,083,128	159,085,830	0	0	0	0	0	0	0	0	0		
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total Cost of Sales		2,676,514,614	259,809,914	278,813,385	291,747,010	305,340,566	319,779,859	336,227,421	353,627,501	372,083,128	159,085,830	0	0	0	0	0	0	0	0	0		
EBITDA		528,331,431	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-2,367,418	0	0	0	0	0	0	0	0	0		
CAPEX Schedule																						
80% SA R related Capex	100%	202,678,000	202,678,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
100% SA R related Land & Buildings	100%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20% US$ related Capex	100%	53,112,683	53,112,683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total capital		255,790,683	255,790,683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Working Capital																						
		Opening Bal																				
Trade Debtors	365	-	29,985,748	30,362,959	30,758,484	31,177,164	31,520,121	31,865,170	32,241,389	32,620,003	12,880,965	0	0	0	0	0	0	0	0	0		
Stock - Coal		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Capital Creditors		-	(21,023,892)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Trade Creditors		-	(21,354,240)	(22,916,169)	(23,979,206)	(25,096,485)	(26,283,276)	(27,635,131)	(29,065,274)	(30,582,175)	(13,075,548)	-	-	-	-	-	-	-	-	-		
Total Working Capital	$6,543,835.43	-	(12,392,383)	7,446,790	6,779,278	6,080,679	5,236,845	4,230,039	3,176,115	2,037,828	(194,582)	-	-	-	-	-	-	-	-	-		
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Change in total working capital		0	12,392,383	(19,839,174)	667,512	698,599	843,833	1,006,806	1,053,924	1,138,287	2,232,411	(194,582)	-	-	-	-	-	-	-	-		
Taxation before financial items		100,876,710	-	-	-	6,692,950	28,887,427	34,616,013	12,359,651	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-		
Change to Cash ("Petty Cash")		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$10,962,366.96		-246,575	-138,904,457	-41,737,114	36,248,235	43,807,019	58,470,951	79,596,245	56,344,652	58,302,157	56,844,013	56,223,025	50,604,335	84,278,224	2,690,518	-182,717	0	0			

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Hydr Excav Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Stand alone cash flow	$44,623,973.25	171,664,038	-138,381,614	70,763,441	83,148,728	67,987,241	35,671,359	17,856,268	27,337,010	14,339,043	-7,573,080	515,643	0	0	0	0	0	0	0	0	0	0
Cummulative cash flow		0	-138,381,614	-67,618,174	15,530,554	83,517,795	119,189,154	137,045,421	164,382,432	178,721,475	171,148,395	171,664,038	171,664,038	171,664,038	171,664,038	171,664,038	171,664,038	171,664,038	171,664,038			
Interest (payable)/received		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Loan repayment		-																				
Investment Income received		-																				
Change in taxation due to interest charge		19,114,486	0	0	0	0	0	0	0	3,674,843	3,846,821	4,154,748	8,148,298	-710,225	0	0	0	0	0	0		
Dividends and STC paid		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Cash Flow after financing		190,778,523	-138,381,614	70,763,441	83,148,728	67,987,241	35,671,359	17,856,268	27,337,010	18,013,886	-3,726,259	4,670,391	8,148,298	-710,225	0	0	0	0	0	0		
		0																				

Depreciation Schedule

ACCOUNTING DEPRECIATION

Period of depreciation of new assets	9.00
Historical per - P & M	9
Historical per - Buildings	9
Commence depreciation	2005
Life of mine (from commence date)	9

10

		TOTAL DEPR	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	
Opening Bal - Plant & machinery	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	
2004	255,790,683	255,790,683	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	0.00
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	0.00
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.00
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	0.00
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0.00
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0.00
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.00
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.00
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.00
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.00
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	-	0.00
2018	0	0															-	-	-	-	-	-	-	-	-	-	-	0.00
2019	0	0																-	-	-	-	-	-	-	-	-	-	0.00
2020	0	0																	-	-	-	-	-	-	-	-	-	0.00
2021	0	0																		-	-	-	-	-	-	-	-	0.00
																					-	-	-	-	-	-	-	
	255,790,683	255,790,683	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	28,421,187	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Check	0.00																										

TAX DEPRECIATION

Period of depreciation of new assets	1
Historical per - P & M	-
Historical tax value	-

		TOTAL DEPR	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Opening Bal - Plant & machinery		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
2004	255,790,683	255,790,683	255,790,683	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#######
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2009	0	0						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	1	-
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	-
2018	0	0															-	-	-	-	-	-	-	-	-	-	1	-
2019	0	0																-	-	-	-	-	-	-	-	-	1	-
2020	0	0																	-	-	-	-	-	-	-	-	1	-
2021	0	0																		-	-	-	-	-	-	-	1	-
2022	0	0																			-	-	-	-	-	-	1	-
2023	0	0																				-	-	-	-	-	1	-
2024	0	0																					-	-	-	-	1	-
2025	0	0																						-	-	-	1	-
2026	0	0																							-	-	1	-
2027	0	0																								-	1	
2028	0	0																										
	255,790,683	255,790,683	255,790,683	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Check	-																										

Taxation Schedule

RING FENCED MINE

Tax rate	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
STC Rate	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%
TFreceived - (Tax Factor) to be applied	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
TFpaid - (Tax Factor) to be applied	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%

TAX CALCULATION - Income Statement

OPERATING PROFIT (excl depr)	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-2,367,418	0	0	0	0	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LESS DEPRECIATION	-28,421,187	-28,421,187	-28,421,187	-28,421,187	-28,421,187	-28,421,187	-28,421,187	-28,421,187	-28,421,187	0	0	0	0	0	0	0	0	0	0	0
TOTAL	76,595,499	62,181,427	54,060,028	45,560,404	35,293,765	23,044,288	10,221,550	-3,627,610	-30,788,605	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	76,595,499	62,181,427	54,060,028	45,560,404	35,293,765	23,044,288	10,221,550	-3,627,610	-30,788,605	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - FINANCIAL : (Dr) / Cr.	22,978,650	18,654,428	16,218,008	13,668,121	10,588,130	6,913,286	3,066,465	(1,088,283)	(9,236,581)	-	-	-	-	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax paid

OPERATING PROFIT (excl depr)	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-2,367,418	0	0	0	0	0	0	0	0	0	0	0
Profit available for Unredeemed capital	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit /loss before Wear and Tear	105,016,686	-60,171,383	22,309,832	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-	-	-	-	-	-	-	-	-	-	-	-
LESS Wear and Tear	-255,790,683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	0	22,309,832	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-2,367,418	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - BEFORE INTEREST	-	-	6,692,950	22,194,477	19,114,486	15,439,643	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax afteInter.

OPERATING PROFIT (excl depr)	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	(2,367,418)	-	-	-	-	-	-	-	-	-	-	-
INTEREST RECEIVED /(PAYABLE)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit available for Unredeemed capital	105,016,686	90,602,614	82,481,215	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit available for Wear and Tear	105,016,686	-60,171,383	22,309,832	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-	-	-	-	-	-	-	-	-	-	-	-
LESS Wear and Tear	-255,790,683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-150,773,998	-60,171,383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	0	22,309,832	73,981,591	63,714,952	51,465,475	38,642,737	24,793,577	-2,367,418	0	0	0	0	0	0	0	0	0	0	0
TAX PAYABLE - AFTER INTEREST	-	-	6,692,950	22,194,477	19,114,486	15,439,643	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-	-	-	-

TAXATION CASHFLOW - before Interest

First and second payment		-	-	-	6,692,950	22,194,477	19,114,486	15,439,643	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-	-
Third payment		-	-	6,692,950	22,194,477	12,421,536	(6,754,835)	(7,521,664)	(8,001,569)	(8,148,298)	710,225	-	-	-	-	-	-	-	-	-
	-	-	-	6,692,950	28,887,427	34,616,013	12,359,651	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-	-	-
Change in Taxation credit	-	-	(6,692,950)	(15,501,528)	9,772,941	19,176,371	766,830	4,154,748	8,148,298	(710,225)	-	-	-	-	-	-	-	-	-	-

TAXATION CASHFLOW - AfterInterest

First and second payment	-	-	-	-	6,692,950	22,194,477	19,114,486	15,439,643	11,592,821	7,438,073	(710,225)	-	-	-	-	-	-	-	-	-
Third payment		-	-	6,692,950	22,194,477	12,421,536	(6,754,835)	(7,521,664)	(8,001,569)	(12,303,047)	(7,438,073)	710,225	-	-	-	-	-	-	-	-
	-	-	-	6,692,950	28,887,427	34,616,013	12,359,651	7,917,978	3,591,252	(4,864,973)	(8,148,298)	710,225	-	-	-	-	-	-	-	-

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Hydr Excav Model			**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Change in Taxation credit			-	-	(6,692,950)	(15,501,528)	9,772,941	19,176,371	766,830	479,905	4,301,477	(4,864,973)	(8,148,298)	710,225	-	-	-	-	-	-	-	-
Change to Deferred Taxation			22,978,650	18,654,428	9,525,059	-8,526,356	-8,526,356	-8,526,356	-8,526,356	-8,526,356	-8,526,356	-	-	-	-	-	-	-	-	-	-	-
STC TAXATION	**Capitalise=0 Cash=1**																					
Opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation Paid			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creditor STC			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change to STC Balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVIDEND / SHAREHOLDERS ACCOUNT	**Capitalise=0 Cash=1**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividend Rate			33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Opening balance Shareholders Account			-	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends capitilized for the period			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Share Holder's Loan Balance			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends to be paid out			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends paid in cash			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closing balance cash dividends			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
REPAYMENT OF INTERGROUP LOAN																						
Interest payable on Loan			15.0%	12.6%	11.1%	10.5%	9.6%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	0.0%	0.0%
Interest receivable on Loan			12.0%	9.6%	8.1%	7.5%	6.6%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	0.0%	0.0%
Balance brought forward		-	**-**	**(138,381,614)**	**(67,618,174)**	**15,530,554**	**83,517,795**	**119,189,154**	**137,045,421**	**164,382,432**	**182,396,318**	**178,670,059**	**183,340,450**	**191,488,749**	**190,778,523**	**190,778,523**	**190,778,523**	**190,778,523**	**190,778,523**	**190,778,523**	**190,778,523**	**190,778,523**
Amount drawn		-	-138,381,614	70,763,441	83,148,728	67,987,241	35,671,359	17,856,268	27,337,010	14,339,043	-7,573,080	515,643	-	-	-	-	-	-	-	-	-	-
Balance before interest		-	(138,381,614)	(67,618,174)	15,530,554	83,517,795	119,189,154	137,045,421	164,382,432	178,721,475	174,823,238	179,185,702	183,340,450	191,488,749	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523
Amount (paid)/received - Interest		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	(138,381,614)	(67,618,174)	15,530,554	83,517,795	119,189,154	137,045,421	164,382,432	178,721,475	174,823,238	179,185,702	183,340,450	191,488,749	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523
Taxation movement - Interest		19,114,486	-	-	-	-	-	-	-	3,674,843	3,846,821	4,154,748	8,148,298	(710,225)	-	-	-	-	-	-	-	-
Balance at end of period		19,114,486	(138,381,614)	(67,618,174)	15,530,554	83,517,795	119,189,154	137,045,421	164,382,432	182,396,318	178,670,059	183,340,450	191,488,749	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523
		(171,664,038)																				
Average Cashflow			-69,190,807	-102,999,894	-26,043,810	49,524,174	101,353,474	128,117,288	150,713,927	171,551,953	178,609,778	178,927,881	183,340,450	191,488,749	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523	190,778,523
Net cashflow (Interest-taxation)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taxation Portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DCF VALUATION

VALUATION BEFORE FINANCING

Discount Rate	NPV - R 'M	IRR	
10.0%	91.5		
12.0%	228.1	38.3%	81.39959387
14.0%	69.9		88.6733183

VALUATION AFTER FINANCING AND DIVIDENDS

Discount Rate	NPV - R 'M	IRR
#REF!	#REF!	
#REF!	#REF!	

CASH FLOW IN US$-TERMS		US$	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!

VALUATION BEFORE FINANCING

Discount Rate	NPV - US$ 'M	IRR
4.0%	#REF!	
6.0%	#REF!	

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59
Wheel loader Model			**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Macro Economic Indicators																				
US PPI escalation			0.98	0.99	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24
SA PPI escalation			1.09	1.17	1.24	1.31	1.39	1.47	1.56	1.65	1.75	1.86	1.97	2.09	2.21	2.35	2.49	2.64	2.80	2.96
R/$ exchange rates	100%		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
			9.54	9.05	9.22	9.42	9.60	9.59	9.59	9.59										
STATISTICS																				
Income per ton - Nominal terms	Ave. **R/ton**	235.54	**214.59**	**217.29**	**220.12**	**223.12**	**225.57**	**228.04**	**230.73**	**233.44**	**236.36**	**239.43**	**242.56**	**246.10**	**250.07**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Income per ton - Real terms	Ave. **R/ton**	139.38	**197.78**	**186.29**	**178.04**	**170.25**	**162.38**	**154.86**	**147.82**	**141.09**	**134.77**	**128.80**	**123.09**	**117.82**	**112.94**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Profit margin based on cash cost - Real	Ave. **%**	20%	**40%**	**36%**	**34%**	**32%**	**29%**	**27%**	**24%**	**21%**	**18%**	**14%**	**11%**	**7%**	**8%**	**0%**	**0%**	**0%**	**0%**	**0%**
Profit margin based on total cost - Real	Ave. **%**	14%	**35%**	**32%**	**30%**	**28%**	**25%**	**21%**	**18%**	**15%**	**12%**	**9%**	**6%**	**2%**	**-18%**	**0%**	**0%**	**0%**	**0%**	**0%**
Cash production cost - Total tons		10.16	**10.72**	**10.70**	**10.56**	**10.43**	**10.31**	**10.22**	**10.14**	**10.07**	**10.00**	**9.93**	**9.87**	**9.81**	**9.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Cash production cost - Real terms	Ave. **R/ton**	113.00	**119.18**	**118.97**	**117.44**	**115.96**	**114.57**	**113.64**	**112.76**	**111.93**	**111.14**	**110.39**	**109.70**	**109.06**	**104.27**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total Production cost - Nominal terms	**R/ton**	194.24	**138.61**	**148.06**	**154.50**	**161.27**	**168.45**	**179.56**	**188.22**	**197.40**	**207.14**	**217.44**	**228.39**	**240.02**	**296.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total Production cost - Real Terms	Ave. **R/ton**	121.95	**127.75**	**126.94**	**124.96**	**123.05**	**121.26**	**121.94**	**120.59**	**119.31**	**118.11**	**116.97**	**115.90**	**114.91**	**133.70**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total distribution cost - Nominal	Ave. **R/ton**	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total distribution cost - Real	Ave. **R/ton**	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Production Schedule	100%				100%	100%	100%	100%	100%											
Waste (Over-burden)	**t**	205,861,000	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	16,891,159	3,167,092	0	0	0	0	0
Stripping Ratio	Ave.	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.0	0.0	0.0	0.0	0.0
R.O.M Tonnage's	**t**	1,851,304	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	1,998,954	374,804	0	0	0	0	0
Final Yield	**%**		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	0%	0%	0%	0%	0%
Final product produced	**t**	20,707,911	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**1,699,111**	**318,583**	**0**	**0**	**0**	**0**	**0**
Closing stock calculation																				
Opening stock	**t**	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Production	**t**	20,707,911	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	1,699,111	318,583	-	-	-	-	-
Total product sold	**t**	-20,707,911	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(1,699,111)**	**(318,583)**	**-**	**-**	**-**	**-**	**-**
- Market	**t**	-20,707,911	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(1,699,111)	(318,583)	-	-	-	-	-
	t	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closing stock	**t**	-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Stock value per ton	**R/ton**	0	**138.61**	**148.06**	**154.50**	**161.27**	**168.45**	**179.56**	**188.22**	**197.40**	**207.14**	**217.44**	**228.39**	**240.02**	**296.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Sales Schedule	100%																			
Sales Price																				
- Market	**$/t**	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00
	$/t	$23.30	21.46	21.73	22.01	22.31	22.56	22.80	23.07	23.34	23.64	23.94	24.26	24.61	25.01	25.43	25.89	0.00	0.00	0.00
Revenue																				
- Market	**R**	4,764,722,969	364,611,147	369,197,836	374,007,219	379,098,144	383,268,333	387,463,939	392,038,578	396,642,324	401,604,769	406,825,631	412,140,457	418,157,708	79,666,884	0	0	0	0	0
	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gross Revenue	**R**	4,764,722,969	364,611,147	369,197,836	374,007,219	379,098,144	383,268,333	387,463,939	392,038,578	396,642,324	401,604,769	406,825,631	412,140,457	418,157,708	79,666,884	0	0	0	0	0
LESS : Distribution Cost	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Sales	**R**	4,764,722,969	**364,611,147**	**369,197,836**	**374,007,219**	**379,098,144**	**383,268,333**	**387,463,939**	**392,038,578**	**396,642,324**	**401,604,769**	**406,825,631**	**412,140,457**	**418,157,708**	**79,666,884**	**0**	**0**	**0**	**0**	**0**
Distribution cost schedule	100%																			
Export via RBCT	100%																			
- Road	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Rail	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Port	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution cost RBCT																				
- Road	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Rail	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Port	**R**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Export via BMA (Durban)	100%																			
- Road	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Rail	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Port	**R/t**	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution cost BMA (Durban)	**R**																			
- Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Rail		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Port		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total distribution cost	**R**	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total :																				
- Road	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Rail	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Port	**R/t**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost of Sales Schedule	100%																			
80% Variable cost	100%	3,499,131,591	211,228,481	226,678,524	237,193,711	248,245,431	259,984,743	273,356,803	287,503,270	302,507,910	318,408,349	335,237,847	353,120,826	372,117,228	73,548,467	0	0	0	0	0
- Mine		2,975,863,565	179,640,898	192,780,507	201,723,229	211,122,250	221,106,039	232,478,411	244,509,383	257,270,195	270,792,847	285,105,624	300,314,342	316,469,979	62,549,863	0	0	0	0	0
- Plant handling cost - discard		8,161,893	492,701	528,739	553,266	579,044	606,427	637,618	670,615	705,614	742,703	781,958	823,671	867,981	171,555	0	0	0	0	0
- Plant opex		507,851,117	30,656,927	32,899,289	34,425,425	36,029,431	37,733,232	39,674,003	41,727,169	43,904,888	46,212,619	48,655,191	51,250,661	54,007,729	10,674,555	0	0	0	0	0
- Laboratory cost		7,255,016	437,956	469,990	491,792	514,706	539,046	566,771	596,102	627,213	660,180	695,074	732,152	771,539	152,494	0	0	0	0	0
- Royalties		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80% Fixed cost	100%	137,505,741	8,478,886	9,099,064	9,521,152	9,964,777	10,436,003	10,972,768	11,540,619	12,142,918	12,781,175	13,456,725	14,174,562	14,937,093	0	0	0	0	0	0
- Mine		137,505,741	8,478,886	9,099,064	9,521,152	9,964,777	10,436,003	10,972,768	11,540,619	12,142,918	12,781,175	13,456,725	14,174,562	14,937,093	0	0	0	0	0	0
- Plant		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Maintenance		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Rehabilitation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- Other		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outside services		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Head Office costs (fixed)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Production cost		3,636,637,333	**219,707,367**	**235,777,588**	**246,714,863**	**258,210,208**	**270,420,746**	**284,329,571**	**299,043,889**	**314,650,827**	**331,189,524**	**348,694,572**	**367,295,388**	**387,054,322**	**73,548,467**	**0**	**0**	**0**	**0**	**0**
Change in stock value		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cost of Sales		3,636,637,333	**219,707,367**	**235,777,588**	**246,714,863**	**258,210,208**	**270,420,746**	**284,329,571**	**299,043,889**	**314,650,827**	**331,189,524**	**348,694,572**	**367,295,388**	**387,054,322**	**73,548,467**	**0**	**0**	**0**	**0**	**0**
EBITDA		1,128,085,636	**144,903,779**	**133,420,248**	**127,292,356**	**120,887,936**	**112,847,587**	**103,134,368**	**92,994,688**	**81,991,497**	**70,415,245**	**58,131,060**	**44,845,069**	**31,103,386**	**6,118,417**	**0**	**0**	**0**	**0**	**0**
CAPEX Schedule																				
80% SA R related Capex	100%	199,857,543	162,750,000	0	0	0	0	37,107,543	0	0	0	0	0	0	0	0	0	0	0	0
100% SA R related Land & Buildings	100%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20% US$ related Capex	100%	50,198,443	42,649,371	0	0	0	0	7,549,072	0	0	0	0	0	0	0	0	0	0	0	0
Total capital		250,055,986	**205,399,371**	**0**	**0**	**0**	**0**	**44,656,615**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Working Capital		Opening Bal																		
Trade Debtors	**365**	-	29,968,039	30,345,028	30,740,319	31,158,752	31,501,507	31,846,351	32,222,349	32,600,739	33,008,611	33,437,723	33,874,558	34,369,127	6,547,963	0	0	0	0	0
Stock - Coal		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capital Creditors		-	(16,882,140)	-	-	-	-	(3,670,407)	-	-	-	-	-	-	-	-	-	-	-	-
Trade Creditors		-	(18,058,140)	(19,378,980)	(20,277,934)	(21,222,757)	(22,226,363)	(23,369,554)	(24,578,950)	(25,861,712)	(27,221,057)	(28,659,828)	(30,188,662)	(31,812,684)	(6,045,079)	-	-	-	-	-
Total Working Capital	**$26,078,724.68**	-	**(4,972,240)**	**10,966,048**	**10,462,385**	**9,935,995**	**9,275,144**	**4,806,391**	**7,643,399**	**6,739,027**	**5,787,554**	**4,777,895**	**3,685,896**	**2,556,443**	**502,884**	**-**	**-**	**-**	**-**	**-**
Change in stock value		0	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Change in total working capital		0	**4,972,240**	**(15,938,288)**	**503,662**	**526,391**	**660,851**	**4,468,753**	**(2,837,008)**	**904,372**	**951,473**	**1,009,659**	**1,091,999**	**1,129,453**	**2,053,559**	**502,884**	**-**	**-**	**-**	**-**
Taxation before financial items		297,263,171	-	-	21,877,397	60,065,104	52,576,691	31,932,950	15,131,221	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-
Change to Cash ("Petty Cash")		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$10,962,366.96		-246,575	-138,904,457	-41,737,114	36,248,235	43,807,019	58,470,951	79,596,245	56,344,652	58,302,157	56,844,013	56,223,025	50,604,335	84,278,224	2,690,518	-182,717	0	0	

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Wheel loader Model			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Stand alone cash flow	$215,732,799.66	580,766,479	-55,523,351	117,481,960	105,918,622	61,349,223	60,931,747	31,013,556	75,026,459	54,997,462	46,769,269	38,016,145	28,497,750	18,779,318	-1,159,040	-1,332,641	0	0	0	0	0	0
Cummulative cash flow		0	-55,523,351	61,958,609	167,877,230	229,226,453	290,158,200	321,171,756	396,198,215	451,195,678	497,964,947	535,981,092	564,478,842	583,258,160	582,099,121	580,766,479	580,766,479	580,766,479	580,766,479			
Interest (payable)/received		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Loan repayment		-																				
Investment Income received		-																				
Change in taxation due to interest charge		33,854,276	0	0	0	0	0	0	0	16,310,950	-10,355,081	3,300,957	3,472,875	3,685,256	3,985,797	4,122,505	7,495,491	1,835,525	0	0		
Dividends and STC paid		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Net Cash Flow after financing		614,620,755	-55,523,351	117,481,960	105,918,622	61,349,223	60,931,747	31,013,556	75,026,459	71,308,413	36,414,188	41,317,103	31,970,626	22,464,574	2,826,757	2,789,864	7,495,491	1,835,525	0	0		
		0																				

Depreciation Schedule

ACCOUNTING DEPRECIATION

Period of depreciation of new assets	13.00
Historical per - P & M	13
Historical per - Buildings	13
Commence depreciation	2005
Life of mine (from commence date)	13

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		TOTAL DEPR	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	
Opening Bal - Plant & machinery	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	
2004	205,399,371	205,399,371	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	-	-	-	-	-	-	-	-	-	-	-	13	0.00
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	0.00
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0.00
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	0.00
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	0.00
2009	44,656,615	44,656,615						4,961,846	4,961,846	4,961,846	4,961,846	4,961,846	4,961,846	4,961,846	4,961,846	4,961,846	-	-	-	-	-	-	-	-	-	-	9	0.00
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.00
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	0.00
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0.00
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0.00
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.00
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.00
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	2	0.00
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	0.00
2018	0	0															-	-	-	-	-	-	-	-	-	-	-	0.00
2019	0	0																-	-	-	-	-	-	-	-	-	-	0.00
2020	0	0																	-	-	-	-	-	-	-	-	-	0.00
2021	0	0																		-	-	-	-	-	-	-	-	0.00
																					-	-	-	-	-	-	-	
	250,055,986	250,055,986	15,799,952	15,799,952	15,799,952	15,799,952	15,799,952	20,761,798	20,761,798	20,761,798	20,761,798	20,761,798	20,761,798	20,761,798	20,761,798	4,961,846	0	0	0	0	0	0	0	0	0	0		
	Check	0.00																										

TAX DEPRECIATION

Period of depreciation of new assets	1
Historical per - P & M	-
Historical tax value	-

		TOTAL DEPR	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	PERIODS	
Opening Bal - Buildings		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Opening Bal - Plant & machinery		0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
2004	205,399,371	205,399,371	205,399,371	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#######
2005	0	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2006	0	0			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2007	0	0				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2008	0	0					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2009	44,656,615	44,656,615						44,656,615	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#######
2010	0	0							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2011	0	0								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2012	0	0									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2013	0	0										-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2014	0	0											-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2015	0	0												-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
2016	0	0													-	-	-	-	-	-	-	-	-	-	-	-	1	-
2017	0	0														-	-	-	-	-	-	-	-	-	-	-	1	-
2018	0	0															-	-	-	-	-	-	-	-	-	-	1	-
2019	0	0																-	-	-	-	-	-	-	-	-	1	-
2020	0	0																	-	-	-	-	-	-	-	-	1	-
2021	0	0																		-	-	-	-	-	-	-	1	-
2022	0	0																			-	-	-	-	-	-	1	-
2023	0	0																				-	-	-	-	-	1	-
2024	0	0																					-	-	-	-	1	-
2025	0	0																						-	-	-	1	-
2026	0	0																							-	-	1	-
2027	0	0																								-	1	
2028	0	0																										
	250,055,986	250,055,986	205,399,371	-	-	-	-	44,656,615	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Check	-																										

Taxation Schedule

RING FENCED MINE

Tax rate	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
STC Rate	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%
TFreceived - (Tax Factor) to be applied	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
TFpaid - (Tax Factor) to be applied	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%	95.83%

TAX CALCULATION - Income Statement

OPERATING PROFIT (excl depr)	144,903,779	133,420,248	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LESS DEPRECIATION	-15,799,952	-15,799,952	-15,799,952	-15,799,952	-15,799,952	-20,761,798	-20,761,798	-20,761,798	-20,761,798	-20,761,798	-20,761,798	-20,761,798	-20,761,798	-4,961,846	0	0	0	0	0	0
TOTAL	129,103,828	117,620,297	111,492,405	105,087,984	97,047,635	82,372,570	72,232,891	61,229,699	49,653,448	37,369,262	24,083,271	10,341,588	-14,643,381	-4,961,846	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	129,103,828	117,620,297	111,492,405	105,087,984	97,047,635	82,372,570	72,232,891	61,229,699	49,653,448	37,369,262	24,083,271	10,341,588	-14,643,381	-4,961,846	0	0	0	0	0	0
TAX PAYABLE - FINANCIAL : (Dr) / Cr.	38,731,148	35,286,089	33,447,721	31,526,395	29,114,291	24,711,771	21,669,867	18,368,910	14,896,034	11,210,779	7,224,981	3,102,476	(4,393,014)	(1,488,554)	-	-	-	-	-	-

TAX CALCULATION - Actual tax paid

OPERATING PROFIT (excl depr)	144,903,779	133,420,248	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
Profit available for Unredeemed capital	144,903,779	133,420,248	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit /loss before Wear and Tear	144,903,779	72,924,657	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	-	-	-	-	-	-	-
LESS Wear and Tear	-205,399,371	0	0	0	0	-44,656,615	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	72,924,657	127,292,356	120,887,936	112,847,587	58,477,753	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
TAX PAYABLE - BEFORE INTEREST	-	21,877,397	38,187,707	36,266,381	33,854,276	17,543,326	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-	-	-	-

TAX CALCULATION - Actual tax afteinter.

OPERATING PROFIT (excl depr)	144,903,779	133,420,248	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	-	-	-	-	-	-	-
INTEREST RECEIVED /(PAYABLE)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit available for Unredeemed capital	144,903,779	133,420,248	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
Unredeemed Capital brought forward	-	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit available for Wear and Tear	144,903,779	72,924,657	127,292,356	120,887,936	112,847,587	103,134,368	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	-	-	-	-	-	-	-
LESS Wear and Tear	-205,399,371	0	0	0	0	-44,656,615	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed Capital before Group application	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital utilized by Group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unredeemed capital carried forward	-60,495,592	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL USED FOR CALCULATION	0	72,924,657	127,292,356	120,887,936	112,847,587	58,477,753	92,994,688	81,991,497	70,415,245	58,131,060	44,845,069	31,103,386	6,118,417	0	0	0	0	0	0	0
TAX PAYABLE - AFTER INTEREST	-	21,877,397	38,187,707	36,266,381	33,854,276	17,543,326	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-	-	-	-

TAXATION CASHFLOW - before Interest

First and second payment		-	-	21,877,397	38,187,707	36,266,381	33,854,276	17,543,326	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-	-
Third payment		-	21,877,397	38,187,707	14,388,984	(4,333,431)	(18,723,055)	(5,955,869)	7,054,123	(3,472,875)	(3,685,256)	(3,985,797)	(4,122,505)	(7,495,491)	(1,835,525)	-	-	-	-	-
	-	-	21,877,397	60,065,104	52,576,691	31,932,950	15,131,221	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-	-	-
Change in Taxation credit	-	(21,877,397)	(16,310,310)	23,798,723	18,722,415	14,389,624	(12,767,185)	3,300,957	3,472,875	3,685,256	3,985,797	4,122,505	7,495,491	1,835,525	-	-	-	-	-	-

TAXATION CASHFLOW - AfterInterest

First and second payment	-	-	-	21,877,397	38,187,707	36,266,381	33,854,276	17,543,326	27,898,407	24,597,449	21,124,574	17,439,318	13,453,521	9,331,016	1,835,525	-	-	-	-	-
Third payment		-	21,877,397	38,187,707	14,388,984	(4,333,431)	(18,723,055)	(5,955,869)	7,054,123	(6,773,833)	(7,158,131)	(7,671,053)	(8,108,302)	(11,617,996)	(9,331,016)	(1,835,525)	-	-	-	-
	-	-	21,877,397	60,065,104	52,576,691	31,932,950	15,131,221	11,587,456	34,952,530	17,823,616	13,966,442	9,768,265	5,345,218	(2,286,980)	(7,495,491)	(1,835,525)	-	-	-	-

	"Nominal terms"	Original R:$	9.54	9.62	10.26	10.97	11.72	12.29	12.88	13.49	14.13	14.79	15.46	16.14	16.84	17.54	18.27	19.01	19.80	20.59		
Wheel loader Model			**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Change in Taxation credit			-	(21,877,397)	(16,310,310)	23,798,723	18,722,415	14,389,624	(12,767,185)	(13,009,993)	13,827,956	384,298	512,922	437,249	3,509,693	(2,286,980)	(7,495,491)	(1,835,525)	-	-	-	-
Change to Deferred Taxation			38,731,148	13,408,692	-4,739,985	-4,739,985	-4,739,985	7,168,445	-6,228,539	-6,228,539	-6,228,539	-6,228,539	-6,228,539	-6,228,539	-6,228,539	-1,488,554	-	-	-	-	-	-
STC TAXATION	**Capitalise=0 Cash=1**																					
Opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STC Taxation Paid			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creditor STC			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change to STC Balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DIVIDEND / SHAREHOLDERS ACCOUNT	**Capitalise=0 Cash=1**		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividend Rate			33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%	33.33%
Opening balance Shareholders Account			-	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends capitilized for the period			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Share Holder's Loan Balance			#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Dividends opening balance			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends to be paid out			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dividends paid in cash			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closing balance cash dividends			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
REPAYMENT OF INTERGROUP LOAN																						
Interest payable on Loan			15.0%	12.6%	11.1%	10.5%	9.6%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	9.5%	0.0%	0.0%
Interest receivable on Loan			12.0%	9.6%	8.1%	7.5%	6.6%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	0.0%	0.0%
Balance brought forward		-	**-**	**(55,523,351)**	**61,958,609**	**167,877,230**	**229,226,453**	**290,158,200**	**321,171,756**	**396,198,215**	**467,506,628**	**503,920,816**	**545,237,919**	**577,208,544**	**599,673,119**	**602,499,876**	**605,289,739**	**612,785,230**	**614,620,755**	**614,620,755**	**614,620,755**	**614,620,755**
Amount drawn		-	-55,523,351	117,481,960	105,918,622	61,349,223	60,931,747	31,013,556	75,026,459	54,997,462	46,769,269	38,016,145	28,497,750	18,779,318	-1,159,040	-1,332,641	-	-	-	-	-	-
Balance before interest		-	(55,523,351)	61,958,609	167,877,230	229,226,453	290,158,200	321,171,756	396,198,215	451,195,678	514,275,897	541,936,961	573,735,669	595,987,863	598,514,079	601,167,234	605,289,739	612,785,230	614,620,755	614,620,755	614,620,755	614,620,755
Amount (paid)/received - Interest		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	(55,523,351)	61,958,609	167,877,230	229,226,453	290,158,200	321,171,756	396,198,215	451,195,678	514,275,897	541,936,961	573,735,669	595,987,863	598,514,079	601,167,234	605,289,739	612,785,230	614,620,755	614,620,755	614,620,755	614,620,755
Taxation movement - Interest		33,854,276	-	-	-	-	-	-	-	16,310,950	(10,355,081)	3,300,957	3,472,875	3,685,256	3,985,797	4,122,505	7,495,491	1,835,525	-	-	-	-
Balance at end of period		33,854,276	(55,523,351)	61,958,609	167,877,230	229,226,453	290,158,200	321,171,756	396,198,215	467,506,628	503,920,816	545,237,919	577,208,544	599,673,119	602,499,876	605,289,739	612,785,230	614,620,755	614,620,755	614,620,755	614,620,755	614,620,755
		(580,766,479)																				
Average Cashflow			-27,761,676	3,217,629	114,917,920	198,551,842	259,692,327	305,664,978	358,684,986	423,696,946	490,891,262	522,928,889	559,486,794	586,598,204	599,093,599	601,833,555	605,289,739	612,785,230	614,620,755	614,620,755	614,620,755	614,620,755
Net cashflow (Interest-taxation)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taxation Portion			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DCF VALUATION

VALUATION BEFORE FINANCING

Discount Rate	NPV - R 'M	IRR
10.0%	337.4	
12.0%	398.8	194.8%
14.0%	279.4	

81.39959387
88.6733183

VALUATION AFTER FINANCING AND DIVIDENDS

Discount Rate	NPV - R 'M	IRR
#REF!	#REF!	
#REF!	#REF!	

CASH FLOW IN US$-TERMS	US$	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!

VALUATION BEFORE FINANCING

Discount Rate	NPV - US$ 'M	IRR
4.0%	#REF!	
6.0%	#REF!	

APPENDIX F – PRODUCTION SCHEDULE

Bench height (m)		Buffelshoek-west	Donkerpoort-west	Donkerpoort-nek	Kwaggashoek-east	**Total**	**Stripping ratio**
3	**Waste**	43,257,000	89,758,000	28,972,000	43,874,000	**205,861,000**	**8.45**
	Ore	7,100,000	9,700,000	2,425,000	5,150,000	**24,375,000**	
6	**Waste**	43,897,000	90,448,000	29,172,000	44,274,000	**207,791,000**	**9.26**
	Ore	6,460,000	9,010,000	2,225,000	4,750,000	**22,445,000**	
9	**Waste**	44,537,000	91,238,000	29,407,000	44,524,000	**209,706,000**	**10.21**
	Ore	5,820,000	8,220,000	1,990,000	4,500,000	**20,530,000**	
12	**Waste**	45,117,000	91,948,000	29,637,000	45,104,000	**211,806,000**	**11.49**
	Ore	5,240,000	7,510,000	1,760,000	3,920,000	**18,430,000**	
15	**Waste**	45,677,000	92,728,000	29,817,000	45,234,000	**213,456,000**	**12.72**
	Ore	4,680,000	6,730,000	1,580,000	3,790,000	**16,780,000**	

	Target	**2,000,000**	**03/04**	**04/05**	**05/06**	**06/07**	**07/08**	**08/09**	**09/10**	**10/11**	**11/12**	**12/13**	**13/14**	**14/15**	**15/16**	**Total**
3 meter	**waste**	**205,861,000**	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	16,891,158.97	3,167,092.31	**205,861,000**
	ROM ore	**24,375,000**	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	375,000	**24,375,000**
																-
6 meter	**waste**	**207,791,000**	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	18,515,571.40	4,119,714.64	-	**207,791,000**
	ROM ore	**22,445,000**	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	445,000		**22,445,000**
																-
9 meter	**waste**	**209,706,000**	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	20,429,225.52	5,413,744.76	-		**209,706,000**
	ROM ore	**20,530,000**	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	530,000			**20,530,000**
																-
12 meter	**waste**	**211,806,000**	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	22,984,915.90	4,941,756.92	-			**211,806,000**
	ROM ore	**18,430,000**	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	430,000				**18,430,000**
																-
15 meter	**waste**	**213,456,000**	25,441,716.33	25,441,716.33	25,441,716.33	25,441,716.33	25,441,716.33	25,441,716.33	25,441,716.33	25,441,716.33	9,922,269.37	-	-			**213,456,000**
	ROM ore	**16,780,000**	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	780,000					**16,780,000**

APPENDIX G – CAPITAL SCHEDULE

rope	Haultruck	Drill	shovel
3	R13,500,000	R800,000	R68,000,000
6	R13,500,000	R1,500,000	R68,000,000
9	R13,500,000	R1,500,000	R68,000,000
12	R13,500,000	R8,000,000	R68,000,000
15	R13,500,000	R8,000,000	R68,000,000

wheel	Haultruck	Drill	shovel
3	R13,500,000	R800,000	R10,500,000
6	R13,500,000	R1,500,000	R10,500,000
9	R13,500,000	R1,500,000	R10,500,000
12	R13,500,000	R8,000,000	R10,500,000
15	R13,500,000	R8,000,000	R10,500,000

exc	Haultruck	Drill	shovel
3	R13,500,000	R800,000	R20,000,000
6	R13,500,000	R1,500,000	R20,000,000
9	R13,500,000	R1,500,000	R20,000,000
12	R13,500,000	R8,000,000	R20,000,000
15	R13,500,000	R8,000,000	R20,000,000

face	Haultruck	Drill	shovel
3	R13,500,000	R800,000	R20,000,000
6	R13,500,000	R1,500,000	R20,000,000
9	R13,500,000	R1,500,000	R20,000,000
12	R13,500,000	R8,000,000	R20,000,000
15	R13,500,000	R8,000,000	R20,000,000

rope	Haultruck	Drill	shovel	total	life
3	-	-	272,000,000	272,000,000	volle leeftyd
6	-	-	272,000,000	272,000,000	
9	-	-	204,000,000	204,000,000	
12	-	-	204,000,000	204,000,000	
15	-	-	204,000,000	204,000,000	

wheel	Haultruck	Drill	shovel		
3	-	-	31,500,000	31,500,000	5jaar
6	-	-	31,500,000	31,500,000	
9	-	-	31,500,000	31,500,000	
12	-	-	42,000,000	42,000,000	
15	-	-	52,500,000	52,500,000	

exc	Haultruck	Drill	shovel		
3	-	-	40,000,000	40,000,000	volle leeftyd
6	-	-	40,000,000	40,000,000	
9	-	-	60,000,000	60,000,000	
12	-	-	60,000,000	60,000,000	
15	-	-	80,000,000	80,000,000	

face	Haultruck	Drill	shovel		
3	-	-	60,000,000	60,000,000	volle leeftyd
6	-	-	60,000,000	60,000,000	
9	-	-	40,000,000	40,000,000	
12	-	-	40,000,000	40,000,000	
15	-	-	60,000,000	60,000,000	

	Price
Haultrcuk budget price	**R13,500,000**
Rope shovel budget price	**R68,000,000**
Hydraulic excavator budget price	**R20,000,000**
Hydraulic face shovel buget price	**R20,000,000**
Wheel loader budget price	**R10,500,000**
251mm Drill rig budget price	**R8,000,000**
165mm Drill rig budget price	**R1,500,000**
114mm Drill rig budget price	**R1,500,000**
65mm Drill rig budget price	**R800,000**

Rope Shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Haultruck		R 121,500,000	R 121,500,000	R 135,000,000	R 135,000,000	R 135,000,000
Drill rigs		R 32,800,000	R 21,000,000	R 12,000,000	R 32,000,000	R 32,000,000
Shovel		R 272,000,000	R 272,000,000	R 204,000,000	R 204,000,000	R 204,000,000
Total Capital cost		**R 426,300,000**	**R 414,500,000**	**R 351,000,000**	**R 371,000,000**	**R 371,000,000**

Hydraulic excavator

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Haultruck		R 121,500,000	R 94,500,000	R 135,000,000	R 135,000,000	R 121,500,000
Drill rigs		R 32,800,000	R 21,000,000	R 12,000,000	R 32,000,000	R 32,000,000
Shovel		R 40,000,000	R 40,000,000	R 60,000,000	R 60,000,000	R 80,000,000
Total Capital cost		**R 194,300,000**	**R 155,500,000**	**R 207,000,000**	**R 227,000,000**	**R 233,500,000**

Hydraulic face shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Haultruck		R 94,500,000	R 135,000,000	R 121,500,000	R 121,500,000	R 135,000,000
Drill rigs		R 32,800,000	R 21,000,000	R 12,000,000	R 32,000,000	R 32,000,000
Shovel		R 60,000,000	R 60,000,000	R 40,000,000	R 40,000,000	R 60,000,000
Total Capital cost		**R 187,300,000**	**R 216,000,000**	**R 173,500,000**	**R 193,500,000**	**R 227,000,000**

Wheel loader

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Haultruck		R 94,500,000	R 135,000,000	R 135,000,000	R 121,500,000	R 148,500,000
Drill rigs		R 32,800,000	R 21,000,000	R 12,000,000	R 32,000,000	R 32,000,000
Shovel		R 31,500,000	R 31,500,000	R 31,500,000	R 42,000,000	R 52,500,000
Total Capital cost		**R 158,800,000**	**R 187,500,000**	**R 178,500,000**	**R 195,500,000**	**R 233,000,000**

ADDENDUM H – DETAIL COST CALCULATIONS

DRILLING COSTS
BLASTING COSTS
LOADING COSTS
HAULING COSTS
SECONDARY COSTS
TOTAL OTHER COSTS
MANPOWER

DRILLING COSTS

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Hole diameter		65mm	114mm	165mm	251mm	251mm
t/m drilled *		7.3	23	49	107	123
R/meter						
Consumables**		15	15.03	17.88	43.7	43.7
Power**		9.56	9.56	9.56	1.00	1.00
Salaries**		6	6	6	6	6
Finance**		7.8	7.8	7.8	7.8	7.8
Maintenance**		5	5	5	5	5
R/meter		43.36	43.39	46.24	63.5	63.5
R/ton drilled		**R 5.940**	**R 1.887**	**R 0.944**	**R 0.593**	**R 0.516**

* Figures obtained from the blast design, see addendum **I**

** Prices were obtained from either contractor quotes or from actual costs.

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Hole diameter		65mm	114mm	165mm	251mm	251mm
t/m		7.3	23	49	107	123
waste tons		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
meters/month req.		192821	67085	34744	17901	17237
m/hour		16	16	16	17	17
hours		12051	4193	2171	1053	1014
hour per drill		300	300	300	300	300
number of drills		**41**	**14**	**8**	**4**	**4**

2 R/kg
16 R/gat

BLASTING COSTS

Bench height		3 meter	6 meter	9 meter	12 meter	15 meter
Hole diameter		65mm	114mm	165mm	251mm	251mm
t/m drilled *		7.3	23	49	107	123
Mass of blasted material (t/hole)		25	158	498	1450	2050
Technical explosives factor ton/kg		3.72	3.82	3.72	3.5	3.64
Explosives cost @ R2/kg **		0.38	0.32	0.33	0.35	0.32
Accessories @ R16/hole **		0.64	0.10	0.03	0.01	0.01
R/ton blasted		R 1.178	R 0.625	R 0.570	R 0.582	R 0.557

* Figures obtained from the balst design, see addendum I
** Prices were obtained from actual costs.

SECONDARY COSTS

Bench height				**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
	Hours/month	R/hour	R/m2*					
Water truck maintenance	200	250	R 2.56	0.267	0.133	0.089	0.067	0.053
Water truck operations	200	100	R 0.32	0.033	0.017	0.011	0.008	0.007
Budozer miantenance	380	800	R 4.86	0.507	0.253	0.169	0.127	0.101
Budozer operation	380	200	R 1.22	0.127	0.063	0.042	0.032	0.025
Wheel dozer maintenance	400	250	R 1.60	0.167	0.083	0.056	0.042	0.033
Wheel dozer operations	400	100	R 0.64	0.067	0.033	0.022	0.017	0.013
totaal R/ton				**R 1.167**	**R 0.583**	**R 0.389**	**R 0.292**	**R 0.233**

* Based on a secondary unit supporting 750,000 tons per month at a desity of 3.2 t/bcm.

Euclid 147

HAULING COSTS

Owning cost	Budget Price	R 13,500,000
	Life of equipment	60000
Total owning	**R/hour**	**671.02**
Maintenance	Servicing cost	54.5
	Repair cost	270.13
Consumables	Fuel/Electricity	319.2
	Wearparts	30
	Lubes	
	Tyres	159.4
Total operating	**R/hour**	**833.23**
Total Cost / hour		**1504.25**
Production rate *		500
Total Cost R/t		**3.01**

* Based on a Talpac simulation over a return distance of 2000m.

Rope Shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		500	500	500	500	500
operating hours / month		370	370	370	370	370
Number of shovels		4.0	4.0	3.0	3.0	3.0
Number of trucks/shovel		2.0	2.0	3.0	3.0	3.0
Number of trucks		**9**	**9**	**10**	**10**	**10**

Hydraulic excavator

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		500	500	500	500	500
operating hours / month		370	370	370	370	370
Number of shovels		2.0	2.0	3.0	3.0	4.0
Number of trucks/shovel		4.0	3.0	3.0	3.0	2.0
Number of trucks		**9**	**7**	**10**	**10**	**9**

Hydraulic face shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		500	500	500	500	500
operating hours / month		370	370	370	370	370
Number of shovels		3.0	3.0	2.0	2.0	3.0
Number of trucks/shovel		2.0	3.0	4.0	4.0	3.0
Number of trucks		**7**	**10**	**9**	**9**	**10**

Wheel loader

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		500	500	500	500	500
operating hours / month		370	370	370	370	370
Number of shovels		3.0	3.0	3.0	4.0	5.0
Number of trucks/shovel		2.0	3.0	3.0	2.0	2.0
Number of trucks		**7**	**10**	**10**	**9**	**11**

Other Costs

Bench height			**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Labour	R/t		1.5	1.5	1.5	1.5	1.5
Fixed costs			2	2	2	2	2
Total Cost R/t			**3.5**	**3.5**	**3.5**	**3.5**	**3.5**

Summary of total mining cost exl. Loading

Bench height			**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
R/ton drilled			**R 5.94**	**R 1.89**	**R 0.94**	**R 0.59**	**R 0.52**
R/ton blasted			**R 1.18**	**R 0.62**	**R 0.57**	**R 0.58**	**R 0.56**
R/ton seconadry			**R 1.17**	**R 0.58**	**R 0.39**	**R 0.29**	**R 0.23**
R/ton hauling			**R 3.00**	**R 3.00**	**R 3.00**	**R 3.00**	**R 3.00**
R/ton other			**R 3.50**	**R 3.50**	**R 3.50**	**R 3.50**	**R 3.50**
Total			**R 14.78**	**R 9.59**	**R 8.40**	**R 7.97**	**R 7.81**

TOTAL OTHER COSTS

LOADING COSTS

			Hydraulic shovel	Wheel loader	Rope shovel
			Hitachi EX2500	CAT 994	P&H 2300
Owning cost	Budget Price		20,000,000	10500000	68000000
	Life of equipment		40000	30000	100000
Total owning	**R/hour**		**R994.10**	**R457.22**	**R1,580.00**
Maintenance	Servicing cost		84.8	54.72	826
	Repair cost		758.32	373.6	
Consumables	Fuel/Electricity		472.65	350.35	17.8
	GET and other		339.92	300	300
	Lubes			52.55	13.17
	Tyres		0	56.75	0
Total operating	**R/hour**		**R1,655.69**	**R1,187.97**	**R1,156.97**
Total Cost / hour			**R2,649.79**	**R1,645.19**	**R2,736.97**

Rope Shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		994	1,245	2,018	2,267	2,267
operating hours / month		370	370	370	370	370
Number of shovels		4.0	4.0	3.0	3.0	3.0
Number of trucks/shovel		2.0	2.0	3.0	3.0	3.0
Loading Cost / ton handled		**R 2.75**	**R 2.20**	**R 1.36**	**R 1.21**	**R 1.21**

Hydraulic excavator

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		2,600	2,122	2,122	1,948	1,560
operating hours / month		370	370	370	370	370
Number of shovels		2.0	2.0	3.0	3.0	4.0
Number of trucks/shovel		4.0	3.0	3.0	3.0	2.0
Loading Cost / ton handled		**R 1.02**	**R 1.25**	**R 1.25**	**R 1.36**	**R 1.70**

Hydraulic face shovel

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		1,318	2,055	2,635	2,635	2,108
operating hours / month		370	370	370	370	370
Number of shovels		3.0	3.0	2.0	2.0	3.0
Number of trucks/shovel		2.0	3.0	4.0	4.0	3.0
Loading Cost / ton handled		**R 2.01**	**R 1.29**	**R 1.01**	**R 1.01**	**R 1.26**

Wheel loader

Bench height		**3 meter**	**6 meter**	**9 meter**	**12 meter**	**15 meter**
Waste tonnage/ annum		16,891,159	18,515,571	20,429,226	22,984,916	25,441,716
Ore tonnage/ annum		2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Production rate t/hour		1,284	1,712	1,712	1,284	1,284
operating hours / month		370	370	370	370	370
Number of shovels		3.0	3.0	3.0	4.0	5.0
Number of trucks/shovel		2.0	3.0	3.0	2.0	2.0
Loading Cost / ton handled		**R 1.28**	**R 0.96**	**R 0.96**	**R 1.28**	**R 1.28**

The production rates were sumilated on Talpac, adjusting cycletimes for the different bench heights.

MANPOWER

Rope Shovel

Bench height	3 meter	6 meter	9 meter	12 meter	15 meter
Haultruck operators	9	9	10	10	10
Drill rig operators	41	14	8	4	4
Seconadry equipment	8	8	6	6	6
General workers	10	10	10	10	10
Shovel operators	4	4	3	3	3
Manpower/shift	72	45	37	33	33
Total manpower	**216**	**135**	**111**	**99**	**99**

Wheel loader

Bench height	3 meter	6 meter	9 meter	12 meter	15 meter
Haultruck operators	7	10	10	9	11
Drill rig operators	41	14	8	4	4
Seconadry equipment	6	6	6	8	10
General workers	10	10	10	10	10
Shovel operators	3	3	3	4	5
Manpower/shift	67	43	37	35	40
Total manpower	**201**	**129**	**111**	**105**	**120**

Hydraulic excavator

Bench height	3 meter	6 meter	9 meter	12 meter	15 meter
Haultruck operators	9	7	10	10	9
Drill rig operators	41	14	8	4	4
Seconadry equipment	4	4	6	6	8
General workers	10	10	10	10	10
Shovel operators	2	2	3	3	4
Manpower/shift	66	37	37	33	35
Total manpower	**198**	**111**	**111**	**99**	**105**

Hydraulic face shovel

Bench height	3 meter	6 meter	9 meter	12 meter	15 meter
Haultruck operators	7	10	9	9	10
Drill rig operators	41	14	8	4	4
Seconadry equipment	6	6	4	4	6
General workers	10	10	10	10	10
Shovel operators	3	3	2	2	3
Manpower/shift	67	43	33	29	33
Total manpower	**201**	**129**	**99**	**87**	**99**

ADDENDUM I – BLAST LAYOUT DESIGN

	Design Parameters	3 meter	Parameters	6 meter	Parameters	9 meter	Parameters	12 meter	Parameters	15 meter	Parameters
Hole diameter (mm)		65		114		165		251		251	
Burden (m)	25 - 30 D	1.625	25.00	2.622	23.00	3.795	23.00	5.02	20.00	5.522	22.00
Spacing (m)	1 - 1.5 B	1.625	1.00	3.1464	1.20	4.554	1.20	7.53	1.50	7.7308	1.40
Bench height (m)	3 B	3	1.85	6	2.29	9	2.37	12	2.39	15	2.72
Sub drill (m)	0.3 - 0.35 B	0.4875	0.30	0.7866	0.30	1.1385	0.30	1.506	0.30	1.6566	0.30
Length of hole (m)		3.4875		6.7866		10.1385		13.506		16.6566	
Stemming (m)	1 B	1.4625	0.90	2.622	1.00	3.795	1.00	5.02	1.00	5.522	1.00
Charge length above floor level (m)	2 B	1.5375	0.95	3.378	1.29	5.205	1.37	6.98	1.39	9.478	1.72
Total charge length (m)		2.025		4.1646		6.3435		8.486		11.1346	
Charging density t/m3	1.2	1.20		1.20		1.20		1.20		1.20	
Exploives / meter (Kg/m)		3.98		12.25		25.66		59.38		59.38	
Explosive mass above floor level (kg)		6		41		134		414		563	
Total explosives mass (kg)		8		51		163		504		661	
Mass of blasted material (t/hole)		25		158		498		1452		2049	
Technical explosives consumption kg/ton		0.24		0.26		0.27		0.29		0.27	
Technical explosives factor ton/kg		4.14		3.83		3.73		3.50		3.64	
Technical explosives factor g/m3 (k)	600 - 900	773		836		859		914		879	
Explosives consumption kg/ton		0.32		0.32		0.33		0.35		0.32	
ton / meter		7.3		23		49		107		123	
Comparitive drilling efficiency		7%		22%		46%		100%		114%	

ADDENDUM J – ECONOMIC EALUATION RESULTS

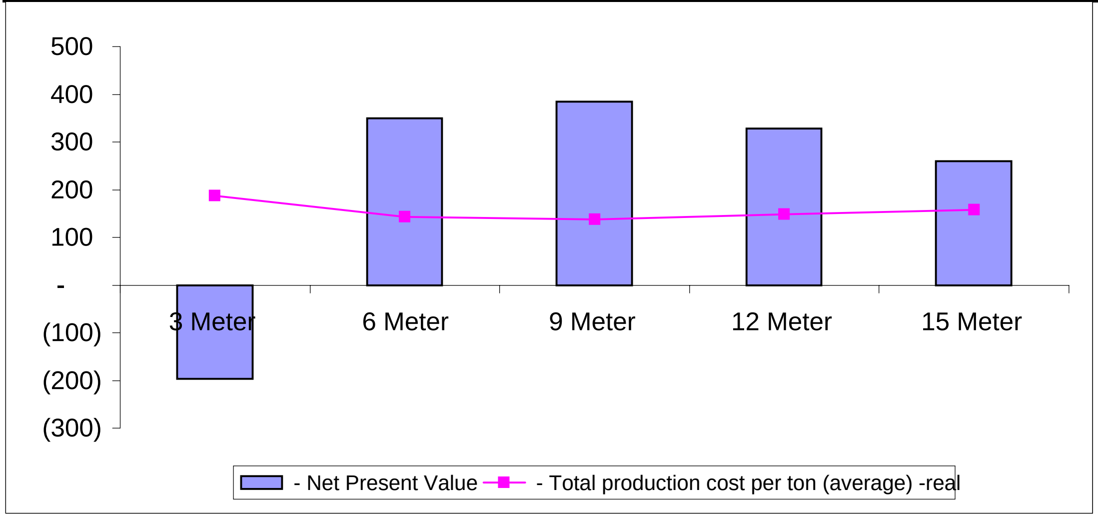
ROPE SHOVEL

HYDRAULIC FACE SHOVEL

HYDRAULIC EXCAVATOR

WHEEL LOADER

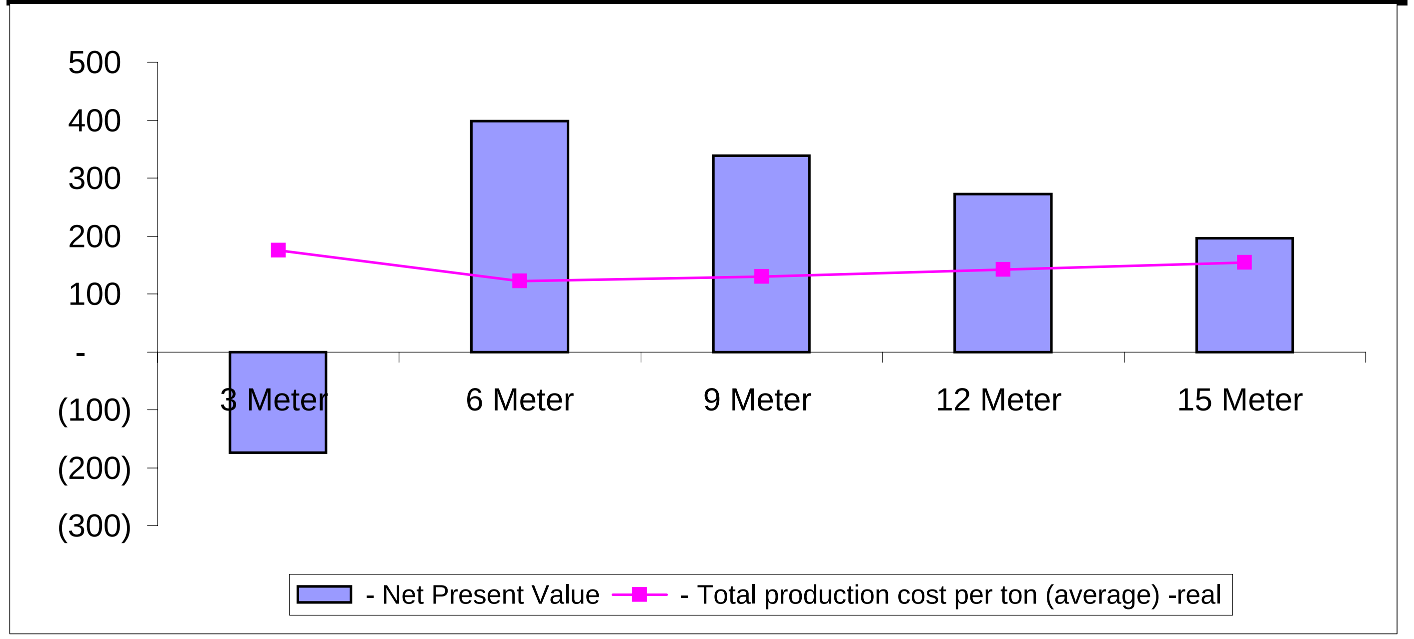
ROPE SHOVEL		**3 Meter**	**6 Meter**	**9 Meter**	**12 Meter**	**15 Meter**
- Net Present Value	**R' m**	**(197)**	**350**	**385**	**329**	**260**
- IRR	**%**	**#DIV/0!**	**17%**	**34%**	**22%**	**10%**
- Gross cash profit margin	**%**	**-21%**	**12%**	**15%**	**12%**	**8%**
-Gross profit margin	**%**	**-33%**	**0%**	**6%**	**1%**	**-1%**
- Cash production cost per ton (average) - Real	**R/t**	**170**	**125**	**120**	**127**	**136**
- Total production cost per ton (average) -real	**R/t**	**187**	**144**	**137**	**149**	**158**
- Cash production cost per ton (total tons) - Real	**R/t**	**15.31**	**10.39**	**9.12**	**8.64**	**8.41**



3	6	9	12	15
(197)	**350**	**385**	**329**	**260**
#DIV/0!	**17%**	**34%**	**22%**	**10%**
-21%	**12%**	**15%**	**12%**	**8%**
-33%	**0%**	**6%**	**1%**	**-1%**
170	**125**	**120**	**127**	**136**
187	**144**	**137**	**149**	**158**
15.31	**10.39**	**9.12**	**8.64**	**8.41**

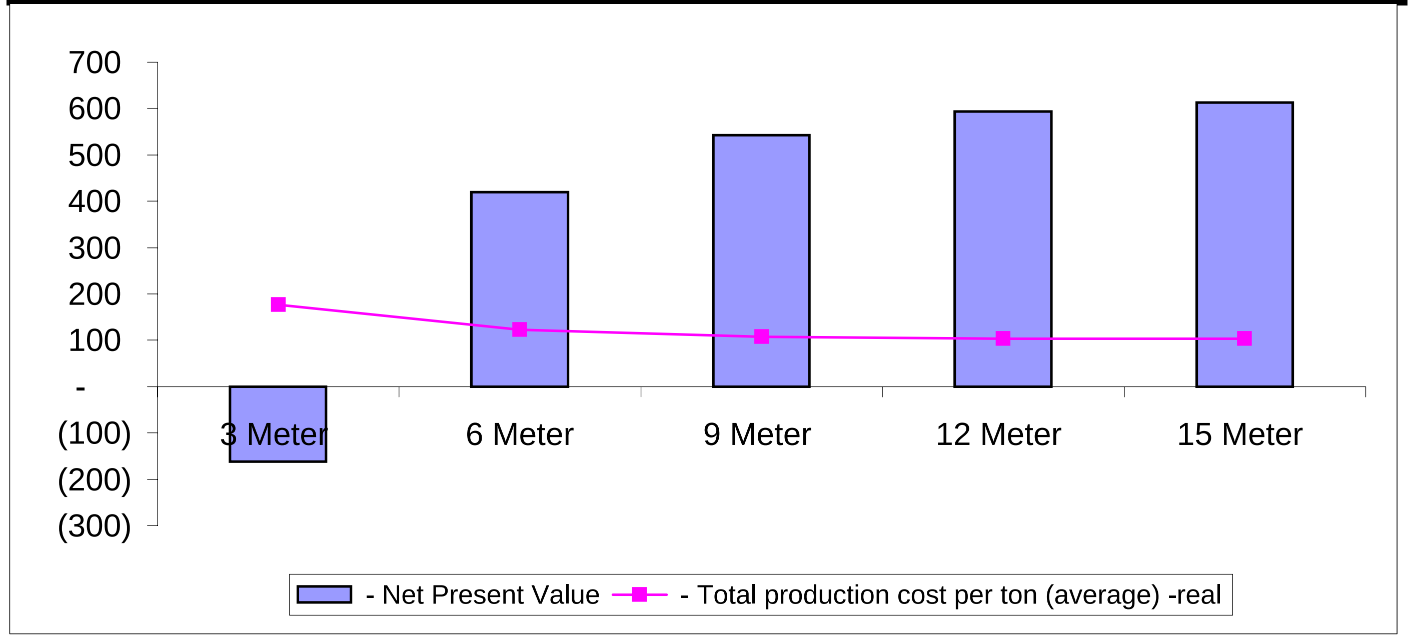
WHEEL LOADER		**3 Meter**	**6 Meter**	**9 Meter**	**12 Meter**	**15 Meter**
- Net Present Value	**R' m**	**(174)**	**399**	**339**	**272**	**197**
- IRR	**%**	**#DIV/0!**	**195%**	**181%**	**97%**	**32%**
- Gross cash profit margin	**%**	**-19%**	**20%**	**16%**	**12%**	**8%**
-Gross profit margin	**%**	**-25%**	**14%**	**10%**	**4%**	**0%**
- Cash production cost per ton (average) - Real	**R/t**	**168**	**113**	**120**	**127**	**137**
- Total production cost per ton (average) -real	**R/t**	**176**	**122**	**130**	**142**	**154**
- Cash operating cost per ton (total tons) - Real	**R/t**	**15.10**	**10.16**	**9.08**	**8.67**	**8.47**

3	6	9	12	15
(174)	**399**	**339**	**272**	**197**
#DIV/0!	**195%**	**181%**	**97%**	**32%**
-19%	**20%**	**16%**	**12%**	**8%**
-25%	**14%**	**10%**	**4%**	**0%**
168	**113**	**120**	**127**	**137**
176	**122**	**130**	**142**	**154**
15.10	**10.16**	**9.08**	**8.67**	**8.47**

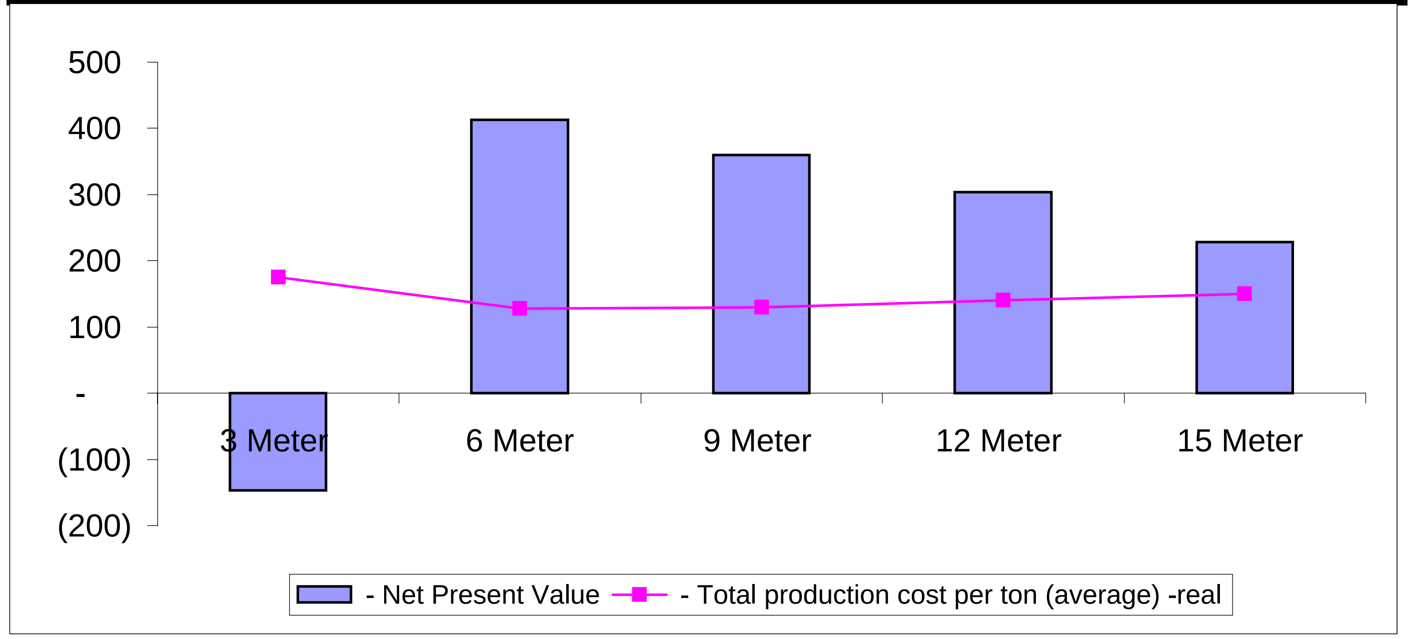


HYDRAULIC FACE SHOVEL		3 Meter	6 Meter	9 Meter	12 Meter	15 Meter
- Net Present Value	R' m	(161)	419	542	594	613
- IRR	%	#DIV/0!	123%	718%	462%	222%
- Gross cash profit margin	%	-20%	20%	29%	33%	34%
-Gross profit margin	%	-25%	14%	24%	27%	27%
- Cash production cost per ton (average) - Real	R/t	169	113	100	96	95
- Total production cost per ton (average) -real	R/t	176	122	107	104	104
- Cash operating cost per ton (total tons) - Real	R/t	15.17	10.20	9.04	8.61	8.51

3	6	9	12	15
(161)	419	542	594	613
#DIV/0!	123%	718%	462%	222%
-20%	20%	29%	33%	34%
-25%	14%	24%	27%	27%
169	113	100	96	95
176	122	107	104	104
15.17	10.20	9.04	8.61	8.51



HYDRAULIC EXCAVATOR		3 Meter	6 Meter	9 Meter	12 Meter	15 Meter
- Net Present Value	R' m	(147)	413	360	304	228
- IRR	%	#DIV/0!	506%	114%	69%	38%
- Gross cash profit margin	%	-19%	21%	15%	12%	8%
-Gross profit margin	%	-24%	17%	10%	5%	2%
- Cash production cost per ton (average) - Real	R/t	167	122	120	127	137
- Total production cost per ton (average) -real	R/t	175	128	130	140	150
- Cash operating cost per ton (total tons) - Real	R/t	15.06	10.99	9.11	8.65	8.46



3	6	9	12	15
(147)	413	360	304	228
#DIV/0!	506%	114%	69%	38%
-19%	21%	15%	12%	8%
-24%	17%	10%	5%	2%
167	122	120	127	137
175	128	130	140	150
15.06	10.99	9.11	8.65	8.46