Analysing the impact of the resource-to-reserve processes on financial viability in mining projects

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ABSTRACT

South Africa has immense mineral resources, historically and contemporarily engendering the mining industry an integral part of the Country's economy. Considerable quantities of money are expended on the evaluation, implementation and eventual extraction of economically valued minerals, for instance gold, platinum, etc. The requisite massive expenditure renders mining houses unable to finance these ventures alone, thus involving financiers, which include, inter alia, banks; venture capitalists and major investment entities, both domestic and foreign. Every operational mine is required to conform to the laws, rules and regulations of the country in which their undertakings occur, thereby involving governments. Furthermore, mining ventures involve multiple diverse, local and international organisations, groups and communities, along with myriad alternate entities and individuals. The number and diversity of stakeholders makes it crucial to ensure a common nomenclature and taxonomy, i.e. a universally understood, shared language, facilitating that everyone comprehends the terminology, lexicon and logic utilised throughout the mining lifecycle. The literature review revealed, however, that this constitutes a major challenge, with a clearly apparent lack of standardisation. Globally, in actuality, multiple dissimilar, varied and distinct international standards and categorisations are utilised.

The Committee for Mineral Reserves International Reporting Standards comprises an international entity that regulates processes involving Mineral Resources and Mineral Reserves. However, this entity is not a regulatory body, with participation and compliance optional. Locally, the South African Code for Reporting of Mineral Resources and Mineral Reserves (SAMREC Code) conforms to this Committee. Companies listed on the Johannesburg Securities Exchange are compelled to comply with the SAMREC Code. The code governs the application of definitions and processes required when reporting Mineral Resources and Mineral Reserves in South Africa. In addition, it endeavours to define and consider the conversion from a Mineral Resource to a Mineral Reserve, termed the resource-to-reserve process.

The resource-to-reserve process is dependent on the application of several modifying factors. However, the SAMREC Code, by design, is vague *vis-à-vis* the actual defining of these modifying factors. The application of modifying factors is left to the interpretation of a Competent Person (CP), who must employ their experience, judgement and logic in the application thereof. Accordingly, each CP will arrive at a different Mineral Reserve. This study focuses on this discrepancy, attempting to identify and establish an enhanced, ameliorated understanding and method for the resource-to-reserve process. The applied modifying factors may appear in the form of percentages or values. Throughout the resource-to-reserve process the available, mineable materials have the potential to either increase or decrease in quantity and/or quality.

Two additional topics of interest, identified for this research comprise: financial modelling and sensitivity analysis. Financial modelling has been established in the study as augmenting the innate uncertainty present in the resource-to-reserve process. As a measure of project's financial viability, Net Present Value (NPV), is deemed as the most suitable and superior. Analogously, research conducted has ascertained that sensitivity analysis constitutes an advantageous and effective method by which to evaluate the impact, of each modifying factor, on the NPV.

A simplified, streamlined case study, utilising an open pit gold deposit is employed to examine and demonstrate the resource-to-reserve process; extending from the development of the geological model, through to the establishment of the financial model and ensuing sensitivity analyses. During this resource-to-reserve conversion procedure, four mining modifying factors are isolated for further investigation, viz. mining losses; dilution loss; oversize; and plant yield loss. By applying sensitivity analysis three of these factors are identified as controlling parameters (factors that significantly impact the project's NPV), constituting plant yield loss; mining loss; and oversize.

Subsequently, the resultant reserve engenders the creation of a mine plan, which is consecutively utilised as the input for the financial model. An additional four economic modifying factors, requiring extended exploration, are established in the formulation of the financial model, viz. variable mining cost; variable processing cost; royalties; and discount factor. Similarly, the application of sensitivity analysis thereto, reveals a significant impact on the NPV.

From the case study, it is concluded that modifying factors from various domains can considerably influence the NPV, denoting that these should be ascribed, implemented and assigned with precision, profound attention and assiduousness. However, the approach adopted in the SAMREC Code renders it extremely challenging to determine the exact manner by which these modifying factors should be applied. Consequently, an added, significant finding arising from this research concerns emphasising auditability. This would facilitate enhanced and augmented straightforwardness, ensuring it being relatively uncomplicated and considerably more effective, when analysing, interpreting, understanding and replicating work performed during the resource-to-reserve process, financial modelling and, ultimately, reporting.

Keywords:

Mineral resource, mineral reserve, modifying factors, SAMREC, project financial model, mining, geology, life of mine, net present value, internal rate of return

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LIST OF DEFINITIONS

Competent Person

The individual(s) responsible for deriving the Mineral Reserve, based on their previous knowledge, experience and judgement. In SA, any mining company listed on the JSE is compelled to have their statements formulated by the work of a competent person(s) (Own definition).

Confidence interval

An uncertainty range, noted as a percentage, which is applied to a value in order to more realistically include the anticipated true value, frequently utilised both positively and negatively (Own definition).

Content

For the purposes of this study, content denotes the economic mineral contained in the ore, e.g. gold (Own definition).

Controlling parameters

Modifying factors that most significantly impact the project value and financial viability (Own definition).

Cut-off grade

Lowest grade of ore economically viable for extraction (Own definition).

Deswik (Deswik.CAD, Deswik.Scheduler and Deswik Software Suite)

Within this investigation, this refers to specialised mining software, which facilitates, *inter alia*, the effective modelling, design and scheduling of a mineral orebody (Own definition).

Dilution

Dilution is as a result of inefficiencies and occurs at the interface between waste and ore. Certain waste is mined as ore and vice versa (Own definition).

Discount factor

This comprises the percentage reduction applied to values in order to render them as present values, i.e. express them in terms of today's worth (Own definition).

Discounted cash flow

For the purposes of this study, this is derived through the application of a discount factor to the free cash flow. A summation of the discounted cash flow, over the life of the project, yields the Net Present Value (Own definition).

Geological model

Within this research, this is an archetype obtained from the interpretation of drilling and exploration results. When this model is sufficiently construed and constrained, the Mineral Resource can be derived (Own definition).

Grade

For this investigation, grade refers to the quantity of gold in the ore, expressed as grams of gold per tonne of ore (Own definition).

In situ

The total ore contained, in an undisturbed state, underground (Own definition).

Life of Mine

The anticipated duration, expressed in years, that the mine is expected to be in operation (Own definition).

Mineable material

This includes diluting and contaminating materials, allowing for anticipated losses occurring when the material is mined (SAMREC, 2009:17).

Mining losses

For the purposes of this study, this refers to losses that occur as a result of inefficient mining practices, comprising ore that is not mined. Typically, there is not a clear, visible distinction between ore and waste, consequently, some ore is discarded as waste, or simply not extracted (Own definition).

Modifying factors

These comprise aspects and elements applied to the Mineral Resource, in order to derive the Mineral Reserve. They may be applied in any unit measure, but percentage values are predominant (Own definition).

Net present value

The worth of the project, expressed in terms of today's (present) monetary value, i.e. the time value of money is taken into account (Own definition).

Ore

For this research, this constitutes the material that contains the economically desired mineral(s) i.e. the rock and gold mixture (Own definition).

Oversize

Rocks too large for the plant, as well as certain foreign debris (for instance, branches) mixed in with the ore (Own definition).

Plant yield losses

For this study, this accounts for inefficient processing practices, e.g. fine gold incorrectly discarded from the plant (Own definition).

Qualitative

Data/decisions based on interpretation, e.g. the confidence in the data is based on experience, not fact (Own definition).

Quantitative

Deals with numbers and calculations, i.e. there is auditable structure that can be studied and repeated (Own definition).

Reserve (Mineral Reserve)

"…the economically mineable material derived from a Measured or Indicated Mineral Resource or both." (SAMREC, 2009:17)

Resource (Mineral Resource)

"…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." (SAMREC, 2009:12)

Resource-to-reserve process

For the purposes of this study, this comprises the process from which the Mineral Reserve, expressed in the form of a mine plan, is derived. The modifying factors are applied within this procedure (Own definition).

ROM Material

Within this research, this refers to the mineable ore and waste that will be extracted from the pit, e.g. by means of truck and shovel (Own definition).

Royalties

This is monetary compensation paid to the community where mining takes place, with the intent of giving back and uplifting the community (Own definition).

Sensitivity analysis

This is an investigative tool where one or more key parameters are changed in a predetermined range. The alteration in the resulting output is measured**.** A graph is frequently utilised to visually depict the results (Own definition).

Stakeholder

For this study it includes all individuals, entities or parties, with an interest in, or association with, the project, whether it is financial, social, legal, etc. (Own definition).

Trend line

This is a MS Excel function that draws a line to match data points. The line can also yield the correlation (R^2) between the data and the line, as well as the formula for the line (Own definition).

Waste

Material that has no economic value. In an open pit mine, the waste needs to be removed in order to reach the ore (Own definition).

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL/ ABBREVIATION	DESCRIPTION
$	US Dollar
$/oz	US Dollar per fine ounce
$/t	US Dollar per tonne
$/yr	US Dollar per year
$M	Million Dollars
%	Percentage
º	Degree
ASM	Artisanal Scale Mining
AusIMM	Australian Institute for Mining and Metallurgy
bn	Billion
BR2RE	Basic Resource to Reserve Equation
BRE	Basic Resource Equation
Capex	Capital Expenditure
CEC	Central Empowered Committee
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CMMI	Council of Mining and Metallurgical Institutions
CoM	Chamber of Mines
CP	Competent Person
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
DCF	Discounted Cash Flow
EBIT	Earnings Before Interest and Tax
EBITDA	Earnings Before Interest, Tax, Depreciation and Amortisation
FCF	Free Cash Flow
g/oz	Gram per fine ounce
g/t	Gram per tonne
GASA	Geostatistical Association of South Africa
GDP	Gross Domestic Product

SYMBOL/ ABBREVIATION	DESCRIPTION
GSSA	Geological Society of South Africa
IFDC	International Fertiliser Development Centre
IMM	Institute for Mining and Metallurgy
IRR	Internal Rate of Return
JORC	Joint Ore Reserves Committee
JORC Code	Australasian Code for Reporting of Mineral Resources and Ore Reserves
JSE	Johannesburg Securities Exchange
koz	Kilo ounces
kt	Kilo Tonne
LOM	Life of Mine
m^3	Cubic meters
mamsl	meters above mean sea level
MAR	Minimum Acceptable Return
Moz	Million ounces
MS	Microsoft
Mt	Million tonnes
Mt/yr	Million tonnes per year
N/A	Not Applicable
NGO	Non-Governmental Organisation
NPV	Net Present Value
Opex	Operating Expenditure
ROM	Run of Mine
SA	South Africa
SAIMM	Southern African Institute of Mining and Metallurgy
SAMREC	South African Mineral Resources Committee
SAMREC Code	South African Code for Reporting of Mineral Resources and Mineral Reserves
SME	Society for Mining, Metallurgy, and Exploration
SSM	Small Scale Mining
t	Tonne

SYMBOL/ ABBREVIATION	DESCRIPTION
t/d	Tonne per day
t/m^3	Tonne per cubic meter
UK	United Kingdom
UNFC-2009	United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009
US	United States
USA	United States of America
USGC	United States Geological Society
yr	Year

CHAPTER 1
NATURE AND SCOPE OF THE STUDY

1.1 Introduction

South Africa has vast Mineral Reserves ('reserves'), which renders the mining industry a lucrative, significant and integral sector of the Country's economy. Current mining ventures are continuously adapting and expanding, while prospective undertakings are investigated for future exploitation. All these projects are appraised and evaluated according to their Mineral Resources ('resources') and reserves.

Within the mining environment there is an essential requisite for an effective, harmonised manner by which to convey resources and reserves. Globally, there has been great progress in relation to this, however additional effort is required towards the formulation, establishment and design of a single set of international standards (Rendu, 2000:91). Emphasising the necessity for universally applicable conventions and benchmarks are certain headlines, for instance "Shell Cuts Reserve Estimate 20% as SEC Scrutinises Oil Industry" (Cummins *et al.,* 2014) and scandals, for example the 1997 Bre-X case in Indonesia (Rendu, 2000:91).

Rendu (2000:91-92) asserts that there is a long-standing requirement for international mining industry standards, to ensure effectual, functional communication within the industry, in consort with all relevant stakeholders (investors; community leaders; international agencies; government; etc.). This requisite is intensified by the significant capital entailed in generating wealth from the exploitation of minerals. To achieve sustainable, profitable and practical mining endeavours requires substantial investments, with investors requiring reassurance that their funds are placed in a secure, high-return environment. In addition, reinforcing the necessity for standardised definitions are the concerns of several organisations *vis-à-vis* the socio-economic and environmental impacts of mining undertakings, as well as the obligations and responsibilities of governments for the provision of legislation, rules and regulations relating thereto, intended towards the accomplishment of certain political, environmental and economic objectives. The inadequate and incomplete structure of standards in reporting produces unscrupulous individuals with the opportunity to take advantage thereof, resulting in scandals, similar to the aforementioned. A distinct, specific set of universally adhered to, international standards would allow a 'common language' to facilitate communication, enhancing the quality of information released, interaction and collaboration. The mining companies require a way to divulge their discoveries, in consort with stakeholders needing a clear comprehension of what is being conveyed, enabling them to experience a sense of confidence, reassuring them of the validity and accuracy of the received information.

Currently there are numerous, assorted series of 'local' standards, denoting the paradigms established within a specific country for reporting domestic resources and reserves. The first 'true' set of reporting standards was released in Australasia in 1988, with the Joint Ore Reserves Committee's (JORC) compilation of the 'Australasian Code for Reporting of Mineral Resources and Ore Reserves' (termed the JORC Code). The JORC Code was incorporated into the Australian Stock Exchange in 1989. Subsequently, the US Society for Mining, Metallurgy, and Exploration's 'A Guide for Reporting Exploration Information, Resources, and Reserves', along with a revision of the United Kingdom's standards for reporting of mineral resources and reserves (based largely on the JORC Code), ensued, both in 1991 (Rendu, 2000:92). Subsequently, various national guides were updated following various international meetings held by institutions from the USA (Society for Mining, Metallurgy, and Exploration - SME), Australia (Australian Institute for Mining and Metallurgy - AusIMM), South Africa (Southern African Institute of Mining and Metallurgy – SAIMM), Canada (Canadian Institute of Mining, Metallurgy and Petroleum - CIM) and UK (Institute for Mining and Metallurgy - IMM).

In South Africa, work on defining resources and reserves has been evinced from 1975 and possibly earlier. Van Rensburg (1975:1) contends that there is an extant confusion and uncertainty between the terms resource and reserve. These terms constitute the principal indicators of prospective mineral production, with multiple, diverse factors to consider, inclusive of confidence interval; dynamic nature of reserves; and variability in grade. The conversion from a resource to a reserve is dependent on these aspects; however, the essential component is distinct, well-defined communication of the change. Zwartendyk (1972, as quoted by Van Rensburg (1975:2)) maintains that if the figure's meaning is unclear, it is detrimental and worse than useless, as it engenders misinformation or misinterpretation. Camisani-Calzolari *et al*. (2000:1) state that the initial significant and serious attempt towards establishing a South African code occurred in 1992. A committee, with members arising from the Geological Society of South Africa (GSSA) and Geostatistical Association of South Africa (GASA), was formed in response to a request from the international Council of Mining and Metallurgical Institutions (CMMI), which, in 2001, was renamed the Committee for Mineral Reserves International Reporting Standards (CRIRSCO). The final draft (labelled 'Draft 6') was presented under the auspices of the SAIMM, but rejected by the primary role players, comprising the Johannesburg Securities Exchange (JSE); the SAIMM and the South African Chamber of Mines (CoM). The 'South African Code for Reporting of Mineral Resources and Mineral Reserves' (SAMREC Code) came into effect in 2000. Currently, all companies listed on the JSE are required to comply with, and to conform to the SAMREC Code. The international definitions of resources and reserves are incorporated into the SAMREC Code, in consort with Country specific requirements, for instance the SA guidelines for qualification as a Competent Person (CP). Statements released for use on the JSE, must be based on work enacted by a CP (Rendu, 2000:92-95).

Analogously to several other international codes, the SAMREC Code is intended to provide transparency, materiality and competence, with reference to Exploration Results, resources and reserves. There are additional multiple, significant facets within the SAMREC Code, including Economic Viability and Modifying Factors (as per the Denver Accord) (Camisani-Calzolari *et al*., 2000:2-3). The ensuing points provide explications and definitions of certain elements, quoted from the updated SAMREC Code:

Materiality

> "A Public Report contains all the relevant information that investors and their professional advisors would reasonably require, and expect to find, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources and Mineral Reserves being reported on." (SAMREC, 2009:6)

Transparency

> "The reader of a Public Report must be provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and not be misled." (SAMREC, 2009:6)

Competency

> "The Public Report is based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable Professional Code of Ethics." (SAMREC, 2009:6)

Exploration Results

> "…mineralization not classified as a mineral resource or mineral reserve must be described as a deposit, and the data and information relating to it must be enough to allow a considered and balanced judgement of their significance. Exploration results must include all relevant exploration information, part of which is the location of the deposit. Such reporting must not be presented in a way that unreasonably implies the discovery of potentially economic mineralization." (SAMREC, 2009:11)

Mineral Resource

> "…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, or estimated from specific geological evidence, sampling and knowledge interpreted from an appropriately constrained and portrayed geological model. Mineral Resources are subdivided, and must be so reported, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated or Measured categories." (SAMREC, 2009:12)

Mineral Reserve

> "…the economically mineable material is derived from a Measured or Indicated Mineral Resource or both. It includes diluting and contaminating materials and allows for losses that are expected to occur when the material is mined. Appropriate assessments to a minimum of a Pre-Feasibility Study for a project and a Life of Mine Plan for an operation must have been completed, including consideration of, and modification by, realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors (the modifying factors). Such modifying factors must be disclosed." (SAMREC, 2009:17)

Modifying Factors

> "…include mining, metallurgical, economic, marketing, legal, environmental, social and governmental considerations." (SAMREC, 2009:10)

The foregoing explanations and characterisations clearly demonstrate that all nomenclature and terms are clearly defined, exclusive of the modifying factors, where certain of the dominant factors that should be taken into account are merely mentioned. Despite this comprising a critical component of the resource-to-reserve process, very little guidance is supplied.

Camisani-Calzolari *et al*. (2000:7) highlight that the code is not prescriptive on the techniques to be utilised when estimating resources and reserves. The requirement is, as stated in the preceding definitions, that multiple, specified factors need to be disclosed. The level of confidence or confidence interval in these factors should also be stipulated, which influences the classification of the resources or reserves. The techniques applied are ordinarily based on judgement from prior experience or established practices.

Various methods and techniques are employed to assist in supplying 'accurate' resource and reserve statements. Van der Merwe *et al*. (2007:55) illustrate an example of how wide the spectrum of modifying factors can be. These authors demonstrate all types of information are relevant when estimating reserves, including the addition of data gathered from adjacent properties (a modifying factor not mentioned in the definitions).

Morley *et al*. (1999:293) categorise four qualitative processes which have an impact on the general resource-to-reserve process, viz. ore definition; geological interpretation; resource estimation; and ore reserve estimation and mine planning. Each of these four qualitative processes encompasses a number of tasks, optimisation of which can reduce the uncertainties in estimation. This study focuses on the transition between the latter two processes, i.e. Resource Estimation, and Ore Reserve Estimation and Mine Planning, in conjunction with the impact they effect on the financial viability of a mining project. Specifically related to this, the tasks predominantly refer to the application of modifying factors.

Rozman (1998, as quoted by Morley *et al*., 1999:293) makes a bold statement, contending that any estimate, be it resource or reserve, will be incorrect, although some would be deemed more accurate than others. Morley *et al*. (1999:293) extend, maintaining that when an erroneous reserve is the primary input into a financial model, the model's results will also be inaccurate. The initial area identified for careful consideration comprises the resource and/or reserve. The majority of financial models assume either as an input without uncertainties. Within the resource-to-reserve process; all the uncertainties and estimations contribute and impact on the financial viability of mining ventures. Morley *et al*. (1999:293) emphasise that significant time, along with large sums of money, is expended to estimate Capital Expenditure (Capex) and Operating Expenditure (Opex); forecast future market trends and which discounts to allow and the percentage thereof. Contrastingly, the authors aver, the input to the financial process, the reserve, is frequently neglected.

The reserve, as an input into the financial model, influences and effects the Net Present Value (NPV); Internal Rate of Return (IRR); Life of Mine (LOM); and other indicators of the project. These variables are the direct drivers of the viability of a mining project. When the inputs (modifying factors) are varied, the financial model's results will change, resulting from an alteration in the grades and tonnages available for extraction and processing.

It is significant to take into account that a number of the inputs to a resource or reserve estimate are qualitative, whereas the financial model has quantitative inputs (Morley *et al*., 1999:294). The four qualitative processes previously described constitute these inputs. For their study, Morley *et al*. (1999:300) simulated and compared various scenarios, whereby within the inputs, a realistic estimate of a 30% uncertainty range or confidence interval was identified, representing both positive and negative uncertainty.

Several companies take great pride in the ability to exceed predicted targets. However, it is deemed ironic that the likelihood of exceeding expectations matches that of not attaining targeted forecasts, as uncertainties vary both positively and negatively. This potential ambiguity characteristic of uncertainties requires companies to make provisions for possible additional costs.

When the focus is shifted to the modifying factors, it is apparent that the application of these is based purely on the interpretation of the CP. Van Kauwenbergh (2010) stresses the lack of standardisation in the resource and reserve terms, with his definitions thereof correlating well with those mentioned in the SAMREC Code. He contends that the description of reserves being deemed as any rock that is economically extractable creates ambiguities and imprecision, which engenders the value/amount completely unrestricted to the interpretation of the CP. Furthermore, this expert asserts that reserves are dynamic, depending on multiple elements, for instance

available technology; market potential; production costs; and commodity prices. A prime example of this interpretive difference is a comparison between estimated reserves of phosphates, which evinced a variance exceeding 300%, between the projected figures established by the United States Geological Society (USGS) and the International Fertiliser Development Centre (IFDC). This denotes that different CPs will invariably arrive at dissimilar reserve estimates, successively directing separate results from the financial model, with the potential for divergent assessments of the financial viability of the project overall.

Meticulous care and attention should be exerted to ensure the correct projects are pursued, subsequent to the foregoing mention of the significance of the mining industry, constituting an important economic sector undergoing continuous expansion, in consort with the associated enormous expenditure, income and investment.

1.2 Problem statement

The preceding information clearly evinces a discrepancy between the qualitative reserve and the quantitative financial model. The reserve is derived from the resource, based on qualitative assumptions composed by the CP. These assumptions are produced with a certain amount of confidence, designated a confidence interval, which is expressed as a percentage and is not properly considered in the financial model. This overtly demonstrates that research into the impact of the resource-to-reserve process on the final financial results is requisite. Typically, prospective mining ventures entail billions of Rands, with minor alterations resulting in NPVs varying by millions of Rands, IRRs changing by a couple of percentage points and LOMs to be adjusted by several year deviations. Consequently, astronomical amounts of money can be wasted on poor projects, although the reverse is also valid, with a project generating profits vastly exceeding projections. These extremes add to the uncertainty of the reserve model's contribution to the financial model.

1.3 Objectives of the study

1.3.1 Introduction

This study is intended to investigate the impact of the resource-to-reserve process (or the modifying factors) on the financial viability (i.e. NPV) of a mining project. The expected outcome is envisaged to engender a better understanding and wider comprehension as to how results can differ when altering the inputs. An additional aim of the study is to investigate how straightforward or difficult it is to make a project appear worthwhile through masking certain critical aspects of concern and vice versa.

1.3.2 Primary objective

The primary objective of this study is to investigate the impact of the qualitative reserve, and the process through which it is derived, on the quantitative financial model. The modifying factors will be investigated to evaluate their impact on the financial model and a project's eventual financial viability.

1.3.3 Secondary objectives

The specific objectives of this study are:

- Determining the major modifying factors that should be considered when transforming a resource into a reserve;
- Investigating the link between the qualitative reserve model and quantitative financial model;
- Establishing the impact of minor changes in the modifying factors on the financial viability of a mining project; and
- Exploring the manipulative ability of the resource-to-reserve process, as measured on the NPV.

1.4 Scope of the study

This study will be quantitative. Stainback and Stainback (1984; cited by Welman *et al*., 2011:8) categorise studies based on numerical calculations, along with those founded on complex structured methods, as quantitative.

An exploratory research design will be employed. USC (2014) asserts that this type of design is appropriate for effectively achieving the following goals:

- Familiarising the researcher with the details of the topic;
- Generating new ideas and assumptions; and
- Determining whether further study is feasible.

These preceding goals align well with what is desired from this study. It is envisioned that the outcome will either comprise a recommendation to accept the current practices or to further investigate them, to arrive at a set structure, together with an array of factors, to follow when converting a deposit from resource to reserve.

The study will focus on the mining sector in South Africa. The SAMREC Code will be utilised as the basis for definitions and logic. The mining industry encapsulates many commodities and types of mining methods. Thus, it is imperative to identify one commodity and general mining method on which to focus. An open pit gold deposit case study will be utilised to investigate the impact of the resource-to-reserve process on the financial viability of a mining project. A case study facilitates a better comprehension and understanding, allowing real world instances to be illustrated via theoretical constructs and concepts. Comparably, Shuttleworth (2008) supports the integration and employment of a case study, averring that it is an appropriate manner by which to condense or narrow a broad field into a single exemplar, which successively can be effectively researched, explicated and scrutinised.

1.5 Research methodology

1.5.1 Literature study

The literature review will focus strongly on obtaining information pertaining to particular constructs or keywords, viz. mineral resource; mineral reserve; modifying factors; project financial model; mining; geology; life of mine; and net present value. The literature review will be conducted utilising extensive scientific research. Certain sources contributing information incorporate, *inter alia*, library resources, for instance databases; scientific and accredited articles on the internet; and relevant textbooks. It is anticipated that the sources that will yield the most applicable and relevant data include SAIMM; AusIMM; and similar government agencies. Alternate databases with potential germane content comprise JSTOR; Juta; ScienceDirect; and GoogleScholar.

1.5.2 Empirical study

The resource-to-reserve process, where the modifying factors are applied, forms the focus of the study. These modifying factors can have an extreme impact on the final outcome of a project. The initial step of this investigation entails the analysis of prior studies pertaining to similar subjects and identify any modifying factors that have been applied therein. The number of factors that will be identified is as yet undetermined, but the study will assist in establishing which modifying factors are important.

The subsequent stage involves applying these factors to the resource-to-reserve process, based on average application standards, as inferred from the studies. Sensitivity analysis will be applied to these modifying factors when they are applied to the financial model, in order to ascertain the eventual impact of making changes to these factors. A typical resource-to-reserve model is portrayed in Figure 1-1.

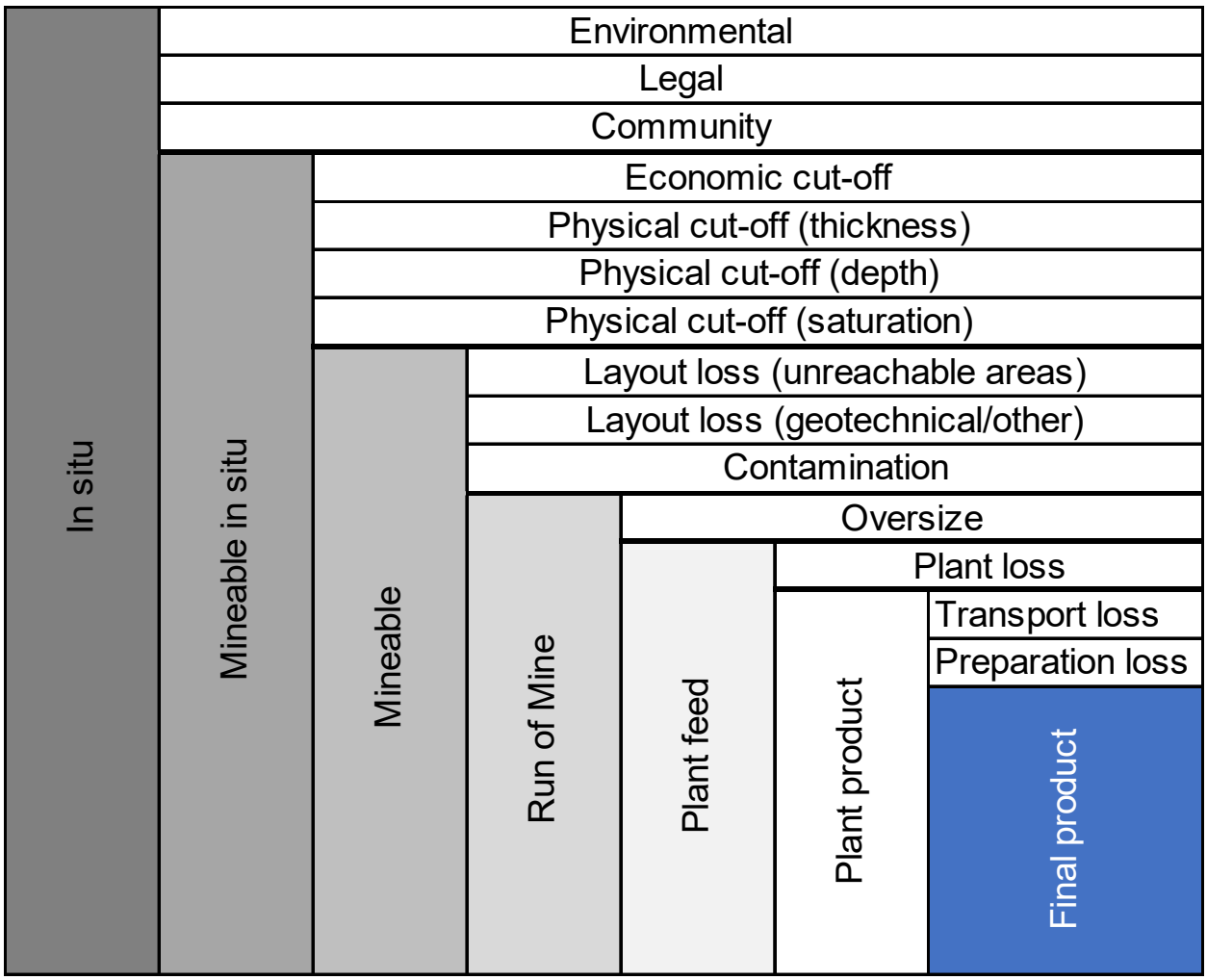

Figure 1-1: Resource-to-Reserve Model

The factors listed to the upper right of the figure are modifying factors for this particular model. As previously stated, the exact modifying factors for sensitivity analysis must be determined, as the first step of the study. These modifying factors impact the reserve in various manners, i.e. increase or decrease the total volume and/or the grade of the economic mineral, as well as multiple alternate possible outcomes.

Once sensitivity analysis has been applied to the modifying factors, the resulting values in the financial model (e.g. NPV) will be plotted to study their true impacts. The NPV refers to the worth of the project in terms of today's (present) monetary value, denoting that the time value of money is taken into account. To achieve this, the factor will be varied and, together with the resulting values, will be graphically plotted to allow visually examination of the impact. A typical example of sensitivity analysis is illustrated in Figure 1-2.

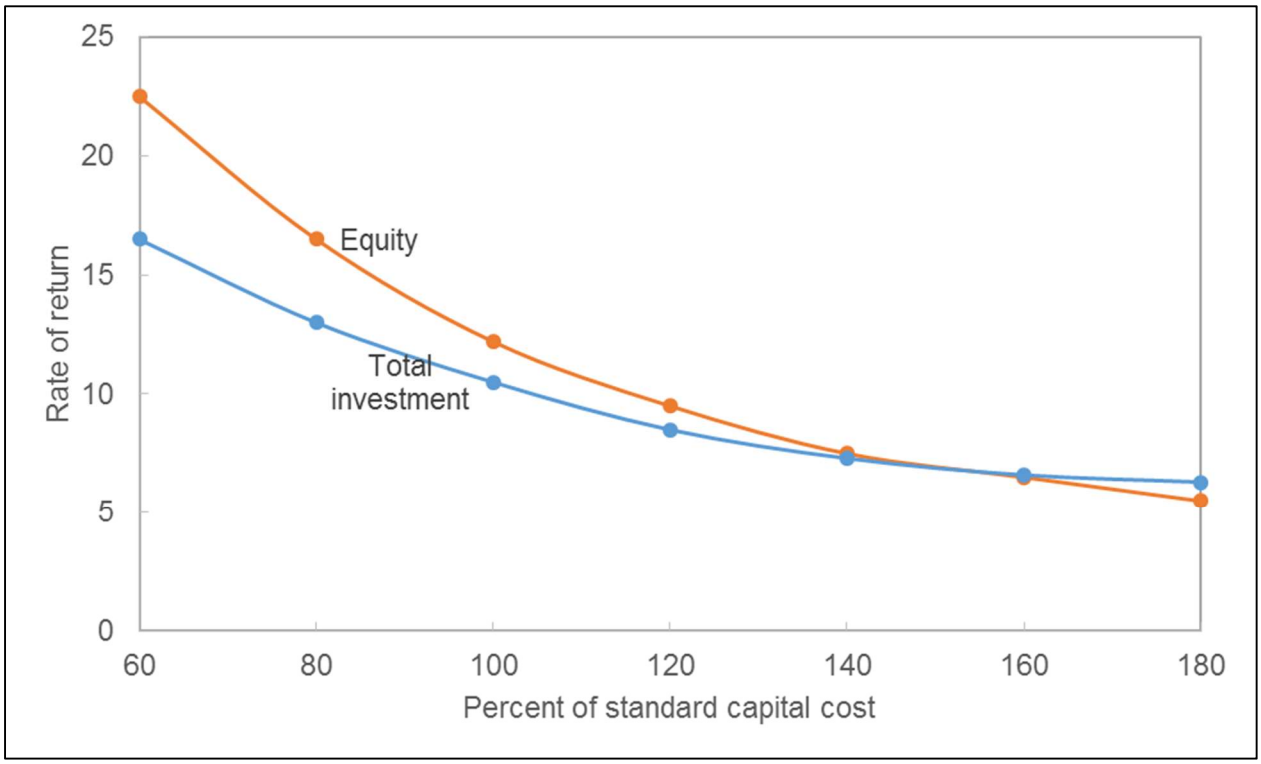

Figure 1-2: Sensitivity Analysis (adapted from Beasley & Pfleider, 1972:112)

As the figure depicts, variations in the percentage of standard capital cost plotted against the rate-of-return evinces different impacts on the equity and total investment. For instance, at 80% the standard capital cost rate-of-return is approximately 13% for total investment and 16.5% for equity. The two lines intersect at approximately 150% standard capital cost. After this point, the IRR for total investment will be higher than the IRR for equity. The same logic and approach will be applied to the modifying factors identified in the study.

1.6 Limitations of the study

The limitations of the study are:

- As a result of the code utilised (SAMREC Code), the results will be most suited to South African projects. Application outside the borders of South Africa should take this into consideration;
- A specific commodity and mining method has been identified. When applying the study to other commodities and mining methods the differences in logic and application need to be taken into account;
- The study will be based on a generic gold deposit case study. The study is explorative and will attempt to give guidance, not exact solutions; and

- Initial research indicates that literature from a wide time range will be used. There is the possibility that certain research within the texts will contain data that has been contemporaneously disproved, refined, or rendered obsolete. Great care will be taken to ensure that all data used is applicable and current.

1.7 Layout of the study

The study is divided into four chapters, as delineated, described and elucidated below.

Chapter 1

Chapter One investigates the overall, broad concept of the study, succinctly outlining what the study concerns. Furthermore, this section encompasses, *inter alia,* the objectives of the study; the broad constructs under which the investigation will be conducted; the identification and expression of the problem statement; along with particular potential limitations of the research.

Chapter 2

The second chapter focuses on research. Three broad topics are identified and explored, viz. the resource-to-reserve process; financial modelling; and sensitivity analysis. This detailed investigation is achieved utilising two phases, an explication of which ensues below.

- Part 1: Addresses the general theoretical aspects of the study, incorporating both established theory (proven and accepted) and contemporary constructs (research conducted within the past 5 years); and

- Part 2: Concentrates on the research area/topic-specific theoretical aspects of the investigation, again equally encompassing established constructs and concepts (confirmed, recognised and acknowledged) and contemporary theory (research undertaken within the past 5 years).

Chapter 3

This chapter assesses the research results which arise from the succeeding exploration approach:

- A simplified case study of an open pit gold deposit is utilised to explain the mining resource-to-reserve process. It explicates the progression from the initial development of the geological model through to the setup of the financial model and sensitivity analyses.

Chapter 4

The final chapter concludes the study and is divided into three sections:

- Conclusions and recommendations for the study;
- Achievement of the objectives; and
- Recommendations for further studies.

CHAPTER 2
LITERATURE REVIEW OF THE RESOURCE-TO-RESERVE PROCESS AND FINANCIAL MODELS

2.1 Introduction

There are multiple exemplars expressing the consensus that there are innate ambiguities associated with the appraisal, estimation and assessment of the potential of ore deposits. For instance, Njowa (2008:1) comments that the “Mineral resource evaluation and estimation process is not an exact science”. Similarly, Rendu (2002:123) discusses several, diverse uncertainties prevalent within a mining project. Geological characteristics remain constant and unaltered during a period a deposit is not being mined or exploited. However, the foremost challenges and concerns relate to limited, inadequate and/or incomplete knowledge of these latent or underlying geological characteristics. Although there is the potential to increase, enhance or improve this information, either via additional exploration work or through superior analysis, it is impossible to accurately predict exactly what is in the ground until it is extracted and processed. This uncertainty is amplified and augmented by unknown future commodity prices.

Macfarlane (2002:37) observes that the SAMREC Code has crucial significance for domestic mining organisations, as well as for foreign investors and mining companies who contribute to, or participate in, this South African industry. Mining constitutes an extremely important sector in the Country, providing a considerable contribution to the Gross Domestic Product (GDP).

Macfarlane (2002:38) reveals that the mining component of the South African GDP constituted in excess of 10% throughout the 1980s, peaking at almost 16% in 1986. This contribution fell, decreasing and stabilising around approximately 7% in the late 1990s. As the figure below depicts, the mining element of the GDP increased once more in the 2000s, appearing to have settled just beneath 10% (See Figure 2-1).

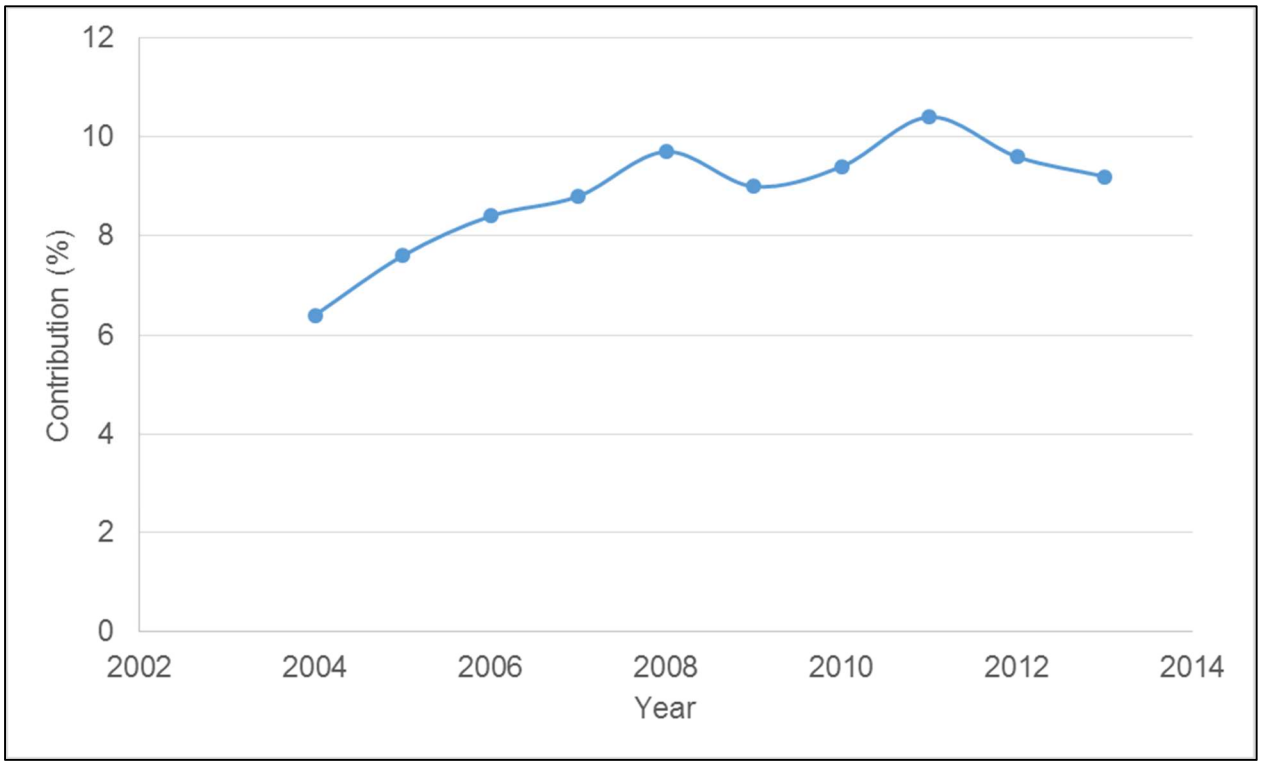

Figure 2-1: Contribution of Mining to SA GDP (SAMI 2013/2014, 2015:22)

Resource and reserve quantities are dependent on various factors. The SAMREC Code notes "…realistic inventory of mineralisation that, at the time of reporting and under assumed and justifiable technical and economic conditions, might become economically extractable" (SAMREC, 2009:13). This signifies that portions of the deposit deemed unreasonable, impractical and unrealistic for eventual economic extraction should not be included in the resource. "In order to emphasise the imprecise nature of a Mineral Reserve estimate, the final results should always be referred to as an estimate, not a calculation", as per the SAMREC (2009:19).

The resource-to-reserve process concerns the assessment and management of risk, with the intention of establishing enough confidence in the reserve to justify the Capex and execution requisite for its exploitation (Weatherstone, 2005:22). The reporting of resources and reserves is for the benefit of involved stakeholders; therefore the information conveyed should be done in a manner which is comprehensible to all relevant parties. A predominance of the critical work required to determine the final reserve is delegated to the CP for interpretation. The CP must utilise his/her knowledge and experience, in conjunction with sound judgement; reasonable assumptions; and elucidations, to derive the best reserve. Figure 2-2 portrays an approach that may be employed to guide mineral asset reporting (Njowa, 2008:1-2).

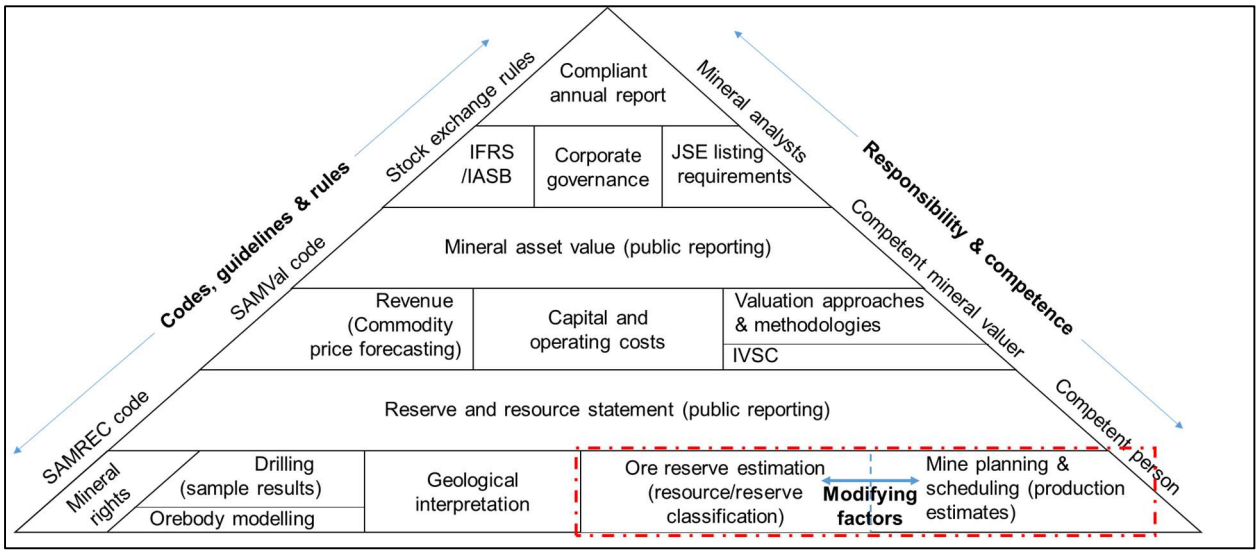

Figure 2-2: Mineral Asset Reporting Triangle, with Associated Risk (Njowa, 2008:3)

The bottom tiers of the triangle encompass the greatest risk for the process. The figure clearly evinces how the basic inputs, for example the resource and reserve, as per the SAMREC Code, form the base of the triangle, upon which all upper tiers are built. The echelons of the triangle are systematically conducted, from left to right and bottom to top. For instance, the bottom level progresses as follows:

- A mining company applies for mineral rights;
- Once the rights are granted, drill sampling can be initiated;
- The subsequent step is for the geologist to construct an orebody;
- The geologist interprets the drilling data;
- This results in a resource (contained in the second block from the right); and
- The modifying factors are applied, as depicted in the final two intertwined blocks on the far right.

The area highlighted with the red dotted line (final step above) comprises the focus of this study. From the preceding explication, it is clearly apparent that the resource and reserve carry significant inherent risk. An identified, associated and critical concern relates to the resource and reserve frequently being automatically accepted at nominal value, thus are assumed to be without uncertainty (Njowa, 2008:2-3).

Geological interpretation is a principal input for the resource and reserve, depicted in Figure 2-2 to the left of the red block. The quality and validity of a geological model is only as accurate as the information from which it is built. Mediocre input data will lead to an inferior geological model, the utilisation of which, in succession, will not add value. In addition to the data, the skill of the CP(s) involved is critical to the effective interpretation of any of these models. Subsequent to resourcing and reserving is the consideration of supplementary elements, comprising the design of facilities; mining infrastructure; selection of equipment; and the resulting LOM plan (Rendu, 2002:127).

Moreover, the organisation, structure and arrangement of the mining operation is extremely important. Weatherstone (2005:18) supplies a very simplistic view, depicting the mine as a contained system (See Figure 2-3).

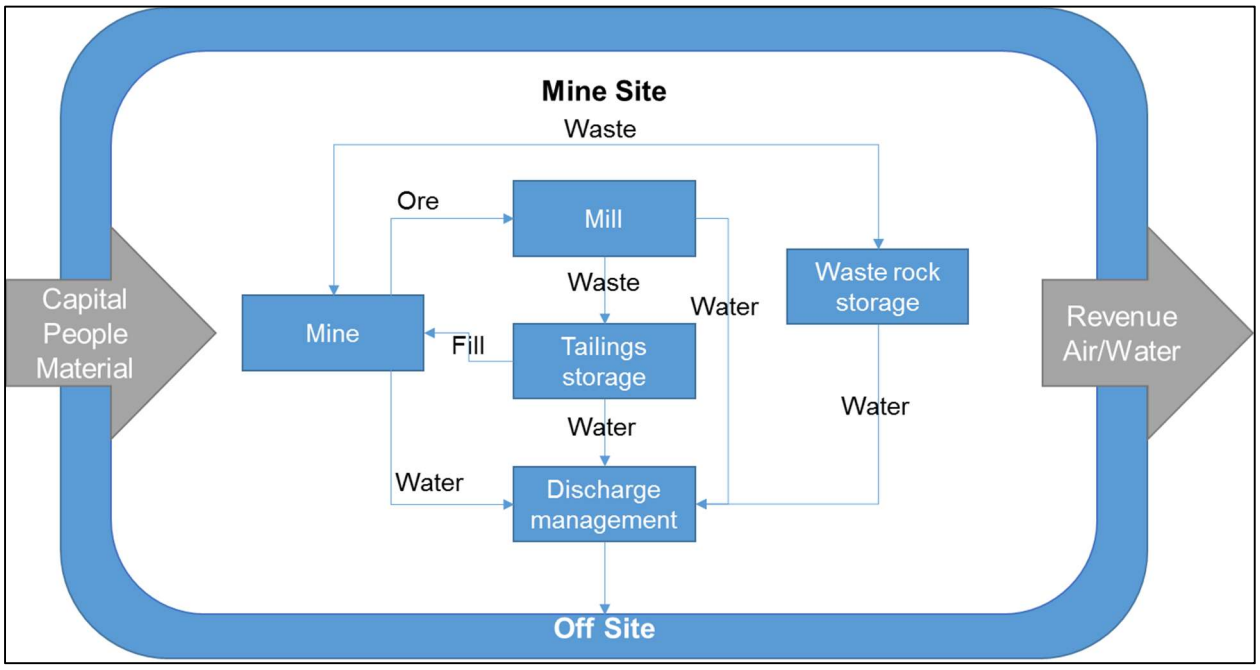

Figure 2-3: Mining Operation as a Contained System (Weatherstone, 2005:18)

This representation delineates a succession of inputs, activities and outputs, whereby capital, people and material enter the system, mining occurs, with revenue and air/water exiting. The central area represents the mine site, where all mining and processing is conducted and the blue border demarcates the off-site (outside market) component. This type of closed system does not allow much room for uncertainty. The utilisation of contained system-logic in financial modelling would engender the assumption of exactly and accurately calculated reserve values.

From the foregoing information it is evident that there are prepared frameworks in position to guide the procedure from prospecting to the eventual stakeholder reporting. Additionally, for financial evaluation purposes, a mine system may be simplified as a contained system that provides ‘exact’ values. The ensuing sections will elucidate and dissect the resource-to-reserve process, in consort with the provision of a more comprehensive review of its progression into financial evaluation.

2.2 International standards

To discern the severity of the requisite of fully comprehending the issues associated with mineral asset reporting, it is imperative to contemplate and consider international developments. Weatherstone (2005:19) asserts that, due to the vast expenditure involved, mining projects require equity investment, as they are too risky (and expensive) to be fully debt funded. An international standard is required, arising from the global economy in which we operate (Clifford, 2005; Stephenson & Weatherstone, 2006:3; Njowa, 2008:1).

The current mining arena has stakeholders from all over the world, however the projects undertaken or those being studied are subject to the regulations, standards and norms of the countries in which they are located (Clifford, 2005). Macfarlane (2002:39) portrays the 1999 domestic control over certain commodities exerted by the South African mining industry (with approximated values), as delineated in Figure 2-4.

The blue bars, in Figure 2-4, illustrate the percentage of domestic control, from which the foreign component or the international contribution per commodity in South Africa can be extrapolated. For example, the iron ore industry was approximately 95% under domestic control, denoting that South African companies were overseeing and directing operations. Only iron ore and gold evince in excess of 50% South African control in 1999. The inference is that the balance of commodities fell under non-domestic admiration and management, signifying the major funding and investment in the Country’s mining industry originates from international investors.

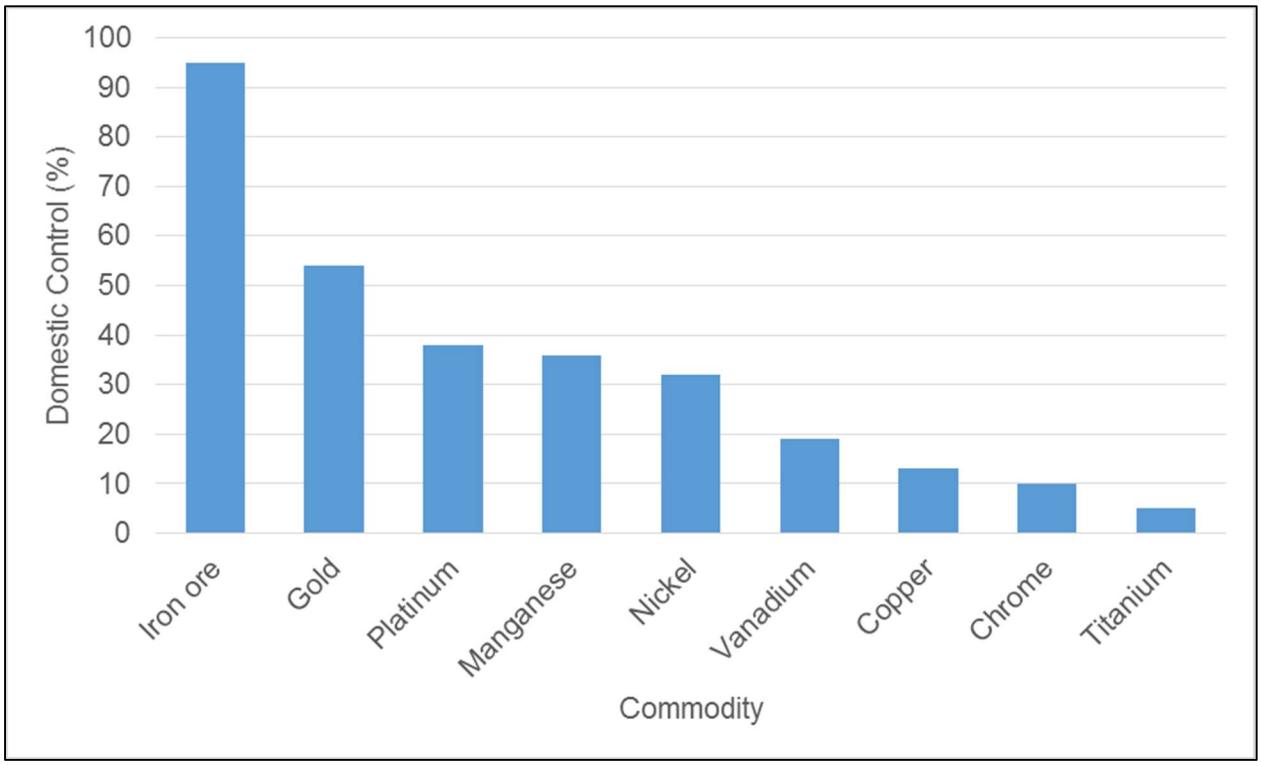

Figure 2-4: Domestic Control over Commodities in 1999 (adapted from Macfarlane, 2002:39)

Subsequent to the discrepancies in reporting approaches, there is no common method for mineral resource accounting, together with no universal lexicon for the disclosure of resources or reserves. This creates a challenge and difficulties, due to the requisite of precise resource measurements for understanding a company's performance and value (Clifford, 2005). Stephenson and Weatherstone (2006:3) and Njowa (2008:1) stress the importance of a standard international reporting system, especially in regard to the rapid globalisation of the mining industry. CRIRSCO (previously CMMI) represents Australia, South Africa, UK/Ireland/ Western Europe, Canada, USA and Chile, facilitating that, in these countries, reporting standards are approximately 90-95% compatible. Several other countries are also developing reporting standards, founded on the CRIRSCO framework. This will greatly enhance and assist in a global comprehension of reported results, thereby aiding investors, legislators and other associates parties in their tasks. To promote global participation and development, CRIRSCO has a 'live' template, which may be downloaded from their website. This template will support any entity or government desiring to establish reporting standards of their own, aligned with those utilised by the foremost major mining nations.

The intent of CRIRSCO is to determine the minimum standard for the reporting of Exploration Results, resources and reserves, in consort with any relevant information required by involved

parties, although CRIRSCO is not a regulating body. The general relationships among Exploration Results, resources and reserves are depicted in Figure 2-2. Stephenson & Weatherstone (2006:6-7) contend that optimising the desired outcomes of reporting is achieved through certain phases, which are explicated below.

- Establishing and prescribing the minimum standards for the public reporting of Exploration Results, resources and reserves;
- Initiating a system for the classification of tonnage (or volume) and grade (or quality) estimates as either resources or reserves, as well as for the subdivision of each into categories which reflect the different degrees of certainty or confidence;
- Specifying the qualifications and experience requisite in a CP;
- Establishing the responsibilities of the CP and companies' Boards of Directors, apropos the reporting of Exploration Results, resources and reserves; and
- Providing a summary list of the main criteria which CP(s) and others should consider in the course of preparing reports on Exploration Results, resources and reserves.

Stephenson and Weatherstone (2006:7&9) attribute the success of CRIRSCO-type reporting standards to their: simplicity; regulatory support; deliberate evasion of excessive prescription; CP system; and industry-friendliness, while taking the investor into account. Table 2-1 lists the countries that conform to CRIRSCO, with the majority having assisted in constructing the CRIRSCO standard.

Table 2-1: List of Countries with CRIRSCO-Type Standards (Stephenson & Weatherstone, 2006:29)

COUNTRY	STANDARD	FIRST PUBLISHED	LATEST EDITION	RESPONSIBLE ORGANISATION(S)
Australasia	Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code)	1989	2004	Australasian Joint Ore Reserves Committee, supported by The Australasian Institute of Mining and Metallurgy, Minerals Council of Australia, Australian Institute of Geoscientists

COUNTRY	STANDARD	FIRST PUBLISHED	LATEST EDITION	RESPONSIBLE ORGANISATION(S)
Canada	CIM Definition Standards on Mineral Resources and Mineral Reserves	2000	2004	Canadian Institute of Mining, Metallurgy and Petroleum.
Chile	Code for the Certification of Exploration Prospects, Mineral Resources and Ore Reserves.	2004	2004	Institute of Mining Engineers of Chile, supported by Chilean Mining Ministry, National Association of Mining, National Association of Geologists and Engineering National Association
South Africa	South African Code for Reporting of Mineral Resources and Mineral Reserves (SAMREC Code)	2000	2006 (in prep)	South African Mineral Resource Committee, supported by South African Institute of Mining and Metallurgy, South African Council for Natural Scientific Professions, Geological Society of South Africa, Geostatistical Association of South Africa, South African Council for Professional Land Surveyors and Technical Surveyors, Association of Law Societies of South Africa, General Council of the Bar of South Africa, Department of Minerals and Energy, Johannesburg Stock Exchange, Council for Geoscience, South African Council of Banks, Chamber of Mines of South Africa
Peru	Code for Reporting on Mineral Resources and Ore Reserves	2003	2003	Joint Committee of the Venture Capital Segment of the Lima Stock Exchange, supported by mining institutions, professionals and specialists in mining exploration.
UK/Ireland/ Western Europe	Code for Reporting of Mineral Exploration Results, Mineral Resources and Mineral Reserves (The Reporting Code)	1991	2001	Pan-European Reserves Reporting Committee, supported by Institute of Materials, Minerals and Mining, Geological Society of London, Institute of Geologists of Ireland, European Federation of Geologists, with industry and stock exchange representation.

COUNTRY	STANDARD	FIRST PUBLISHED	LATEST EDITION	RESPONSIBLE ORGANISATION(S)
USA	Guide for Reporting Exploration Information, Mineral Resources and Mineral Reserves	1992	1999	Committee on Resources and Reserves of the Society for Mining, Metallurgy, and Exploration, Inc.

Each nation has certain country-specific clauses; however the standards are 90-95% compatible. When any countries' standards or codes are updated, a review is conducted by the other CRIRSCO members, as well as by the regulating authority of the specific state. This is undertaken to ensure compliance with all relevant standards.

An overall comparison between the reporting codes of the member countries is delineated in Table 2-2. The table corroborates the similarity between the participating country codes and standards. If an item is marked with an 'X', it means the line item is applicable to the country listed at the top. All the members agree on the principal points, encompassing the adoption of CRIRSCO-type standard; CP requirements; and the advocated and permitted reporting of resources. There are minor variances within the other primary points demarcated above. Clifford (2005) observes that these countries constitute in excess of 80% of the world's Stock Exchange Capital. Weijermars (2015:12) reports that many alternate nations, for instance Russia and China, have formulated their reserve reporting codes to conform to CRIRSCO.

Table 2-2: Comparison of the CRIRSCO Reporting Codes (adapted from Stephenson & Weatherstone, 2006:27)

	AUSTRALASIA	CANADA	SOUTH AFRICA	UK/W EUROPE	CHILE	PERU	USA - SME
Adoption of CRIRSCO-type standard	X	X	X	X	X	X	X
Reporting standard recognised by national regulator	X	X	X	X	X	X	
Competent Person (CP) requirement	X	X	X	X	X	X	X
Reporting of Mineral Resources allowed	X	X	X	X	X	X	X
Inferred Resources allowed in economic studies	X	X*	X	X	X	X	X
Level of study required for Mineral Reserves	1	2	1	2	2	1	1
ROPO-type reciprocal system	X	X	X	X			

Level of study:	1 = Appropriate assessment and studies as determined by CP
	2 = pre-feasibility study – expected (UK/W Europe) or required (Canada/Chile)
	3 = Feasibility study for new projects
ROPO	Recognised Overseas Professional Organisation
X*	Allowed in certain restricted circumstances

Rendu (2002:123) simplifies a mining project into a particular progression of phases, viz. sampling; developing a deposit model; selecting mining and processing methods; estimating costs; and developing a technical and financial LOM plan, with specialists (CPs) employed to estimate and account for uncertainties. These stages analogously align with the processes utilised by the CRIRSCO members. The succeeding section focuses on an investigation of South African regulations.

2.3 SAMREC

Macfarlane (2002:41) reveals that the process to compile the SAMREC Code was initiated in 1998, when the South African Institute for Mining and Metallurgy (SAIMM) instigated and

assembled the South African Mineral Resources Committee (SAMREC). The sole purpose of the Committee was to establish the SAMREC Code – which was instated in 2000. Multiple stakeholders were involved in the process, including representatives from: SAIMM; The South African Council for Natural and Scientific Professions; GSSA; GASA; The South African Council for Professional Land Surveyors and Technical Surveyors; The Association of Law Societies of South Africa; The General Council of the Bar of South Africa; The Department of Minerals and Energy; Johannesburg Securities Exchange (JSE); The Council for Geoscience; The South African Council of Banks; and CoM. A key consequence of the code is the requirement that companies listed on the JSE are required to comply with the specifications delineated therein. To attain an alignment between SAMREC and the JSE, the process depicted in Table 2-3 was followed.

Table 2-3: JSE SAMREC Integration (Macfarlane, 2002:43)

<table>
<tr><th>JSE ⇨ SAMREC</th><th>⇨Panel of readers</th><th>⇨ Panel of readers</th><th>⇨ JSE</th><th>⟺ SAMREC</th></tr>
<tr><td rowspan="6">Refer draft prospectus to SAMREC</td><td rowspan="6">Nominates readers</td><td rowspan="6">Reader signs agreement /contract relating to confidentiality, conflict of interest, responsibilities and deadlines</td><td rowspan="3">1. Readers reviews and checks for compliance with the SAMREC Code and JSE rules</td><td>1. Acknowledges readers report and recommendations</td><td rowspan="2">1. Co-ordinator reviews prospectus /report ito recommendations to JSE</td></tr>
<tr><td>2. Refers back to applicant company/competent person and requests revision</td></tr>
<tr><td>3. Assures anonymity of readers</td></tr>
<tr><td rowspan="3">2. Recommends to JSE modifications, acceptance or rejection</td><td>4. Accepts/rejects reviewed document for listing</td><td rowspan="3">2. Recommends to the JSE modifications, acceptance or rejection</td></tr>
<tr><td>5. Informs SAMREC of all outcomes</td></tr>
<tr><td></td></tr>
</table>

The table illustrates that a stringent and thorough approach was followed to achieve alignment between the JSE and SAMREC. The flow of alignment was from the JSE to SAMREC, then to a panel of readers (twice), and back to the JSE. Subsequently there were various alignment sessions between the JSE and SAMREC, evidenced from the two-way arrow between the ultimate two columns. The outcome is that all public companies need to adhere to the code, resulting in stakeholders having a better understanding of the companies' mineral assets. The SAMREC Code graphically depicts the relationship between resources and reserves, as portrayed in Figure 2-5.

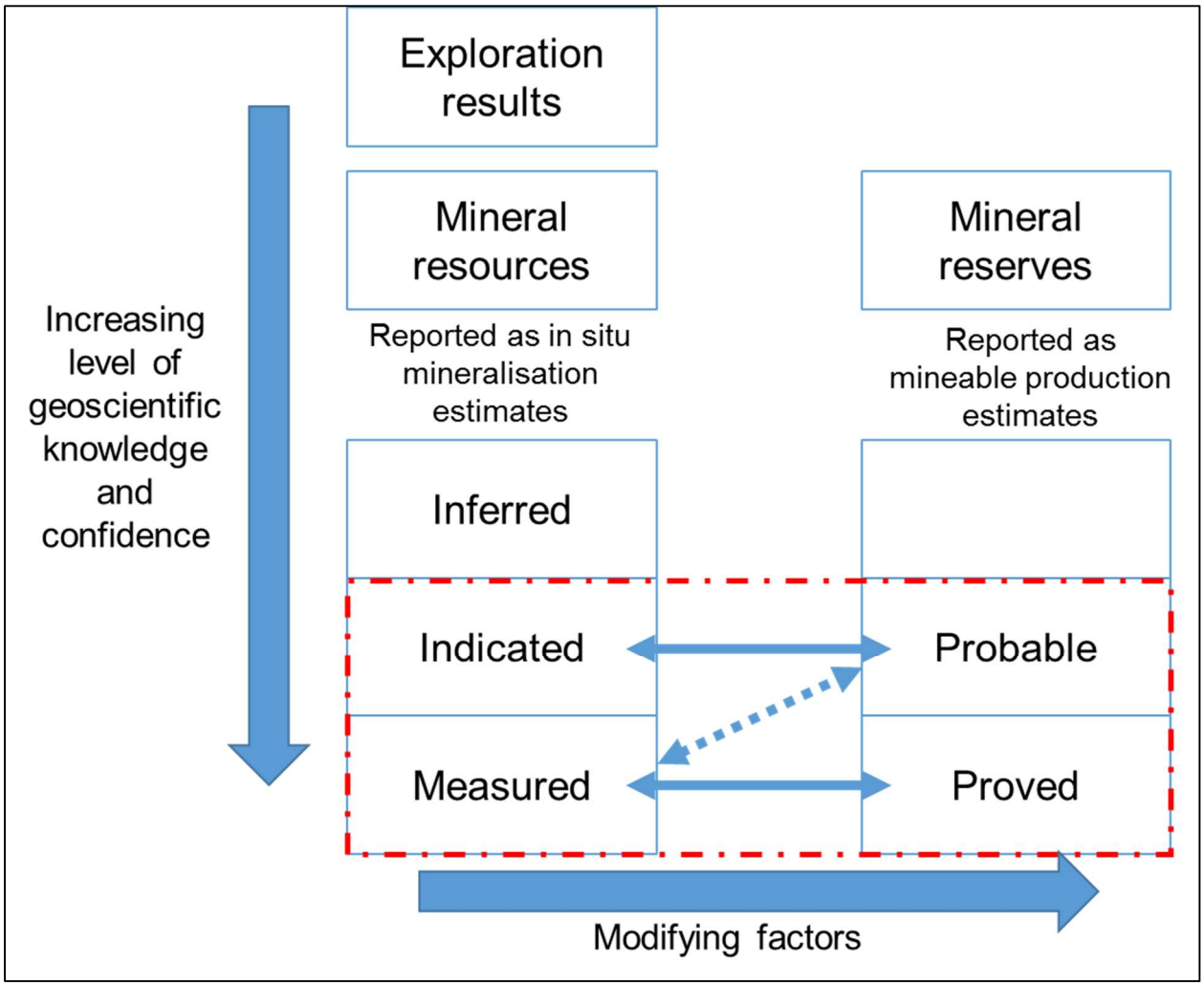

Figure 2-5: Relationship between Resource and Reserve (SAMREC, 2009:10)

The figure indicates that the SAMREC Code has three levels of resource, in increasing levels of confidence, viz. Inferred, Indicated and Measured. The reserve has two possible classifications, viz. Probable and Proved. The optimal reserve to possess is a proved reserve. The level of confidence increases progressively, from top to bottom in the figure. To convert from a resource to a reserve (left to right), modifying factors are applied, these will be elucidated further later in the discourse. A reserve can only be converted from the resources included in the red rectangle. The figure reveals that an indicated resource would typically convert to a probable reserve and a measured resource to a proved reserve. Depending on the level of confidence it is possible that a measured resource will convert to a probable reserve (dashed double arrow). No other combinations are possible. Undertaking the conversion and determining the eventual confidence of the reserve is based on the interpretation of the CP.

This section has highlighted that, even with greater clarity and guidance for the reporting of mineral assets, there are still concerns relating to the accuracy and standardisation of reporting. The following section investigates certain deficits of current calculations.

2.4 Deficits of the current calculations

Baker and Giacomo (1998; quoted by Dimitrakopoulos *et al*., 2007:74) comment that a study of 48 mining projects in the Australasian region revealed that nine evinced lower reserves than anticipated (equal to 19%) and thirteen generated reserves exceeded their forecast (equates to 27%). Dimitrakopoulos *et al*. (2007:74) reinforces the postulate that projects may manifest results which either surpass or fall short of those which were initially forecast. Furthermore, Vallee (2000; referred to by Dimitrakopoulos *et al*., 2007:74) recounts that a survey by the World Bank exposed that 73% of mining projects failed consequent to inaccurate reserve estimates, instigating a loss in capital investments in excess of a billion dollars. Dimitrakopoulos *et al*. (2007:74) observe that there is only a 4% probability that projects will achieve their predicted NPV. A venture's NPV is equal to the sum of its annual Discounted Cash Flow (DCF), denoting that DCF constitutes a beneficial and reliable measure to utilise when exemplifying uncertainty (see Figure 2-6).

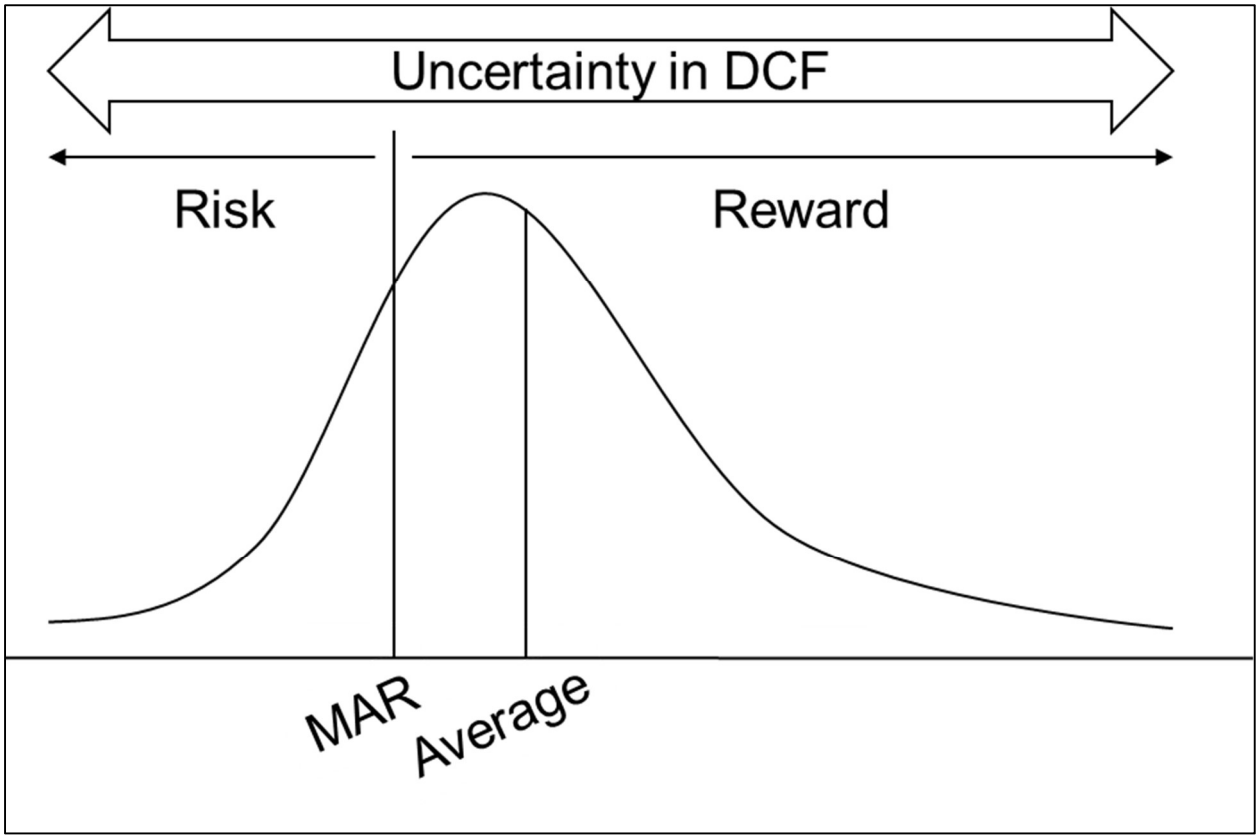

Figure 2-6: Uncertainty Regarding Project Performance (adapted from Dimitrakopoulos *et al*., 2007:75)

For the preceding example, which is grounded on DCF, various, diverse scenarios are executed, based on mine designs, production sequences and geological interpretations. The result is a skewed bell curve with a certain level of risk (left) and reward (right). The Minimum Acceptable Return (MAR) and average are depicted on the x-axis, and are usually discrete, separate and dissimilar. It is deemed significant to highlight that, even if a project produces profits transcending those forecast or anticipated (extreme right), it nevertheless exhibits uncertainty. This creates a concern, substantiating that uncertainty is unavoidable; with the uppermost bar indicating its comprehensive and extensive range in DCF. The calculations utilised in the figure employ the renowned and recognised Lerchs-Grossman equation.

Parhizkar *et al*. (2012:1279) reconciled and correlated estimated grades to actual measurements obtained when mining. They established three factors primarily contribute to grade correspondence uncertainty, viz., in progressive order, systematic uncertainty; inherent variability; and statistical uncertainty. Conducting a sensitivity analysis constitutes one recommended manner by which to investigate uncertainty and the impact thereof and will be elaborated on, later in the discourse.

Figure 2-2 indicates the high risk relayed in the lower levels of the triangle, with the information provided indicating elevated levels of uncertainty. The ensuing section will focus on the modifying factors, which have been identified as the link between the resource and reserve in Figure 2-2.

2.5 Modifying factors

The foregoing research substantiates the conception that there are explicit deficits and requisites for amelioration associated with the assessment of a mining project. The resource-to-reserve process comprises a principal component within the reporting structure. Weatherstone (2005:14) stresses that more consideration is contributed to the geological aspects of resource estimation, as compared to the conversion of a resource to a reserve, which is arrived at through the application of modifying factors. Macfarlane (2002:41) clarifies that the incorporation of modifying factors is conducted in accordance with the Denver Accord; a conference held in 1997, attended by the majority of prominent mining countries.

As mentioned previously, different individuals (CPs) will invariably arrive at disparate reserve estimates. This consequence may be extended and expanded through the incorporation of varying and contrasting scenarios when converting the resource to the reserve. Winterstetter *et al*. (2015:19) reveal that the implementation of four dissimilar scenarios resulted in four distinct resource classifications. Their investigation utilised the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). This framework is analogous to CRIRSCO, with certain misalignments. Furthermore, these authors observed that

the inclusion/exclusion of particular infrastructure may, in addition, affect the project's financial viability, in consort with the resource/reserve classification. Major (and expensive) infrastructure, for instance a new mineral processing plant (Winterstetter *et al.*, 2015:28), can influence the declared resource/reserve. Hence, evaluations need to occur on a case-by-case basis.

Weatherstone (2005:15&17) contends that contemporary routines to derive reserves evince the employment of specialist teams, rather than individuals (a team of CPs, as opposed to a single CP). The primary motivation for this is the wide range of modifying factors, in conjunction with the difficulty associated with their application. The modifying factors overlap, are concomitant, correlated and connected, therefore cannot be addressed in isolation. See the example in Figure 2-7.

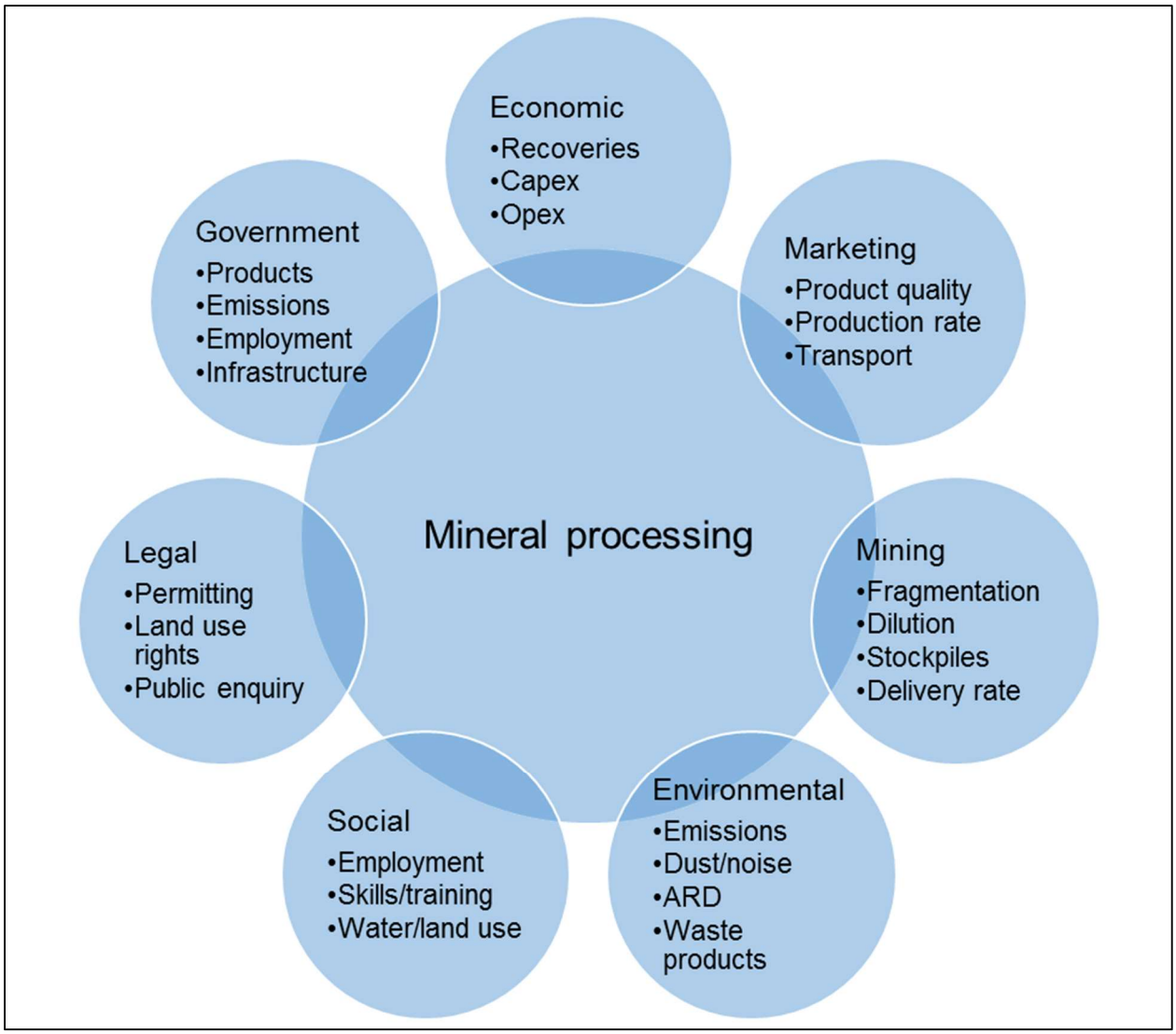

Figure 2-7: Overlap of Modifying Factors, Applied to Mineral Processing (adapted from Weatherstone, 2005:17)

In the foregoing exemplar, modifying factors are applied to mineral processing. Mineral processing is positioned in the middle, with the disciplines, along with their modifying factors, are delineated in the bubbles surrounding mineral processing. The primary areas on which to focus concern the overlap among the requirements of the various disciplines. For instance, 'emissions' occurs in both 'government' and 'environmental' requirements, with 'employment' present in both 'government' and 'social'. If a discipline is viewed as a distinct single element, in isolation, an alternate discipline may be affected and deteriorate, consequentially, the project may become unfeasible. The application of modifying factors is integral to successfully deriving a reserve. The process requires involvement from multiple participating parties and entities, as in Figure 2-8. All those involved can be classified and grouped into three categories, viz. project team; internal; and external.

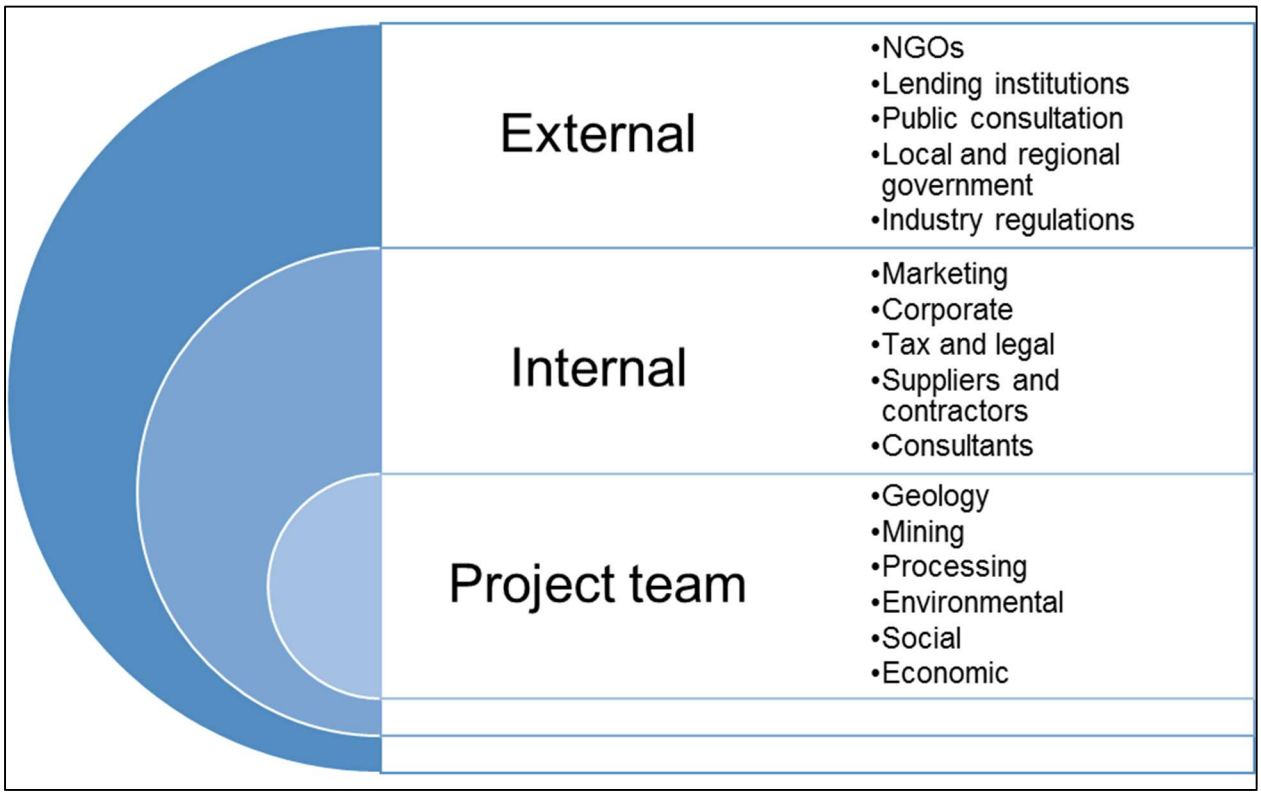

Figure 2-8: Stakeholder Influence (adapted from Weatherstone, 2005:16)

The semi-circles (spheres) to the left indicate the sphere of influence. The smallest area constitutes the area in which the project team has influence. They are responsible for the application of the modifying factors, reserve estimation and eventual project viability. It is deemed significant to highlight that sanction and satisfaction, *vis-à-vis* the results, is required from the parties demarcated by the exterior semi-circles, the internal and external stakeholders. The

influence of the company decreases, progressively from the inner to outer spheres; whereby the central sphere (internal) represents the entity outside the project team and the ultimate, outer sphere (external) denotes the area in which the organisation exerts no effect, being subject to the judgements of the decision makers (Weatherstone, 2005:15-16).

Njowa (2008:12) ascertains certain issues requiring additional attention, which are applicable to the predominance of commodities, directly impacting on the resource-to-reserve process and consequently, the reported assets. For the purposes of this study they are considered synonymous with modifying factors. The concerns are explicated below.

Mining width and equipment used:

- The mining method selected, along with the pit/seam cut-off, contribute an important element when determining the resultant reserve.

Other economic minerals contained in ore:

- Many ore-bodies contain more than one economic mineral, where applicable, these should be included in the evaluation.

Relevant dilution:

- This is possibly of greater relevance to thin ore-bodies, where waste material dilution is unavoidable, it should be included correctly and mineral grades recalculated.

2.5.1 Extended modifying factors

Temper and Martinez-Alier (2013:79) discuss the concerns apropos the financial worth of forests and environmental elements. They establish three principal rationales for the reserve classification process to be non-conducive to the conservation of environmental justice, viz. the deepening of structural inequalities; it instigates financial decision-making without proper participation; and it ignores cultural differences and values.

From the preceding discourse and paragraph it is clearly apparent that modifying factors are far reaching, encompassing a vast majority of issues. This reinforces, as more functional and appropriate, the utilisation of a CP team, which facilitates greater effectiveness and accuracy in the incorporation of relevant modifying factors. The process is complex and intricate, especially taking into account that the potential modifying factors have an extensive range, in conjunction with the requisite establishment of the value of each factor, along with determining the manner by which it should be applied.

2.5.2 Modifying factor magnitude

The value, or magnitude, of a modifying factor is extremely pivotal. For instance, selecting whether a modifying factor is applied as 5% or 10% can have significant impact on the size of the reserve. Temper and Martinez-Alier (2013:82) conducted an investigation into a case where a great variation in the proposed magnitude of a modifying factor was evident. Their case study discusses the discount rate for use in an environmental setup, with the following points demarcating the arguments:

- A professor contended that the social discount rate should be 0%, but recommended the use of 2%;
- A committee recommended the use of a 5% discount rate;
- Business lobbyists maintained a discount rate of 12% was germane; and
- The Central Empowered Committee (CEC) decided to approve a discount rate of 4%.

The argument by the CEC was that a project environment only considers the life of the project; however, taking into account forest or ecological concerns, the impact is experienced over several generations. This type of discrepancy, in deciding the magnitude of the modifying factor, is present in most, if not all, modifying factors and rates utilised during reserve estimation. Furthermore, Temper and Martinez-Alier (2013:82) comment that the CEC placed a value on any forest/open land, based on the density of vegetation; thereby formulating land use as a commodity. The inference of this is that no land is valued in its own right, notwithstanding its specific value; heritage; sacredness; or any alternate facet. Temper and Martinez-Alier (2013:86) assert that “There is simply no correct and possible way to value all aspects of our environment, so some values get left out, complexity is obscured, while valuations are plagued with arbitrariness regarding what to value and the discount rate.”

This section has highlighted that modifying factors can incorporate virtually anything that can be justified, as well as the value thereof is open to interpretation by the CP(s). In accord with the complexity of the process, the succeeding section explores possible approaches intended to simplify the resource-to-reserve process.

2.6 Approaches to simplify the resource-to-reserve process

2.6.1 Reserve replication

Seccatore *et al.* (2014:804) discuss how the reserve estimation differs when scrutinising and surveying small scale projects; termed Artisanal- (ASM) and Small Scale Mining (SSM).

Frequently, these projects have less capital and exploratory undertakings cannot be effectively diffused into the overall costs, which often results in small projects neglecting the proper procedures required to determine resources and reserves. Albeit that these small projects are plagued with problems, for instance illegality and pollution, they offer the potential to mine otherwise uneconomic resources. This prospective achievement arises from their high mobility; and flexibility; in consort with the reduced and minimal planning required; and low capital outlay. In addition to these advantages, this type of operation is highly adaptable to changes in commodity prices and variances in mineral grades.

Rendu (2002:130-31) asserts that the decisions undertaken with regard to the financial expenditure for exploration are reliant on the associated anticipated reward and return. The norm constitutes the probability of exploration success being low, with the possible rewards very high. As available funds are usually restricted, companies sometimes have to choose between certain options, which are demarcated in the ensuing points.

- Investment in green fields (not previously explored) exploration, with the low probability of high return;
- Purchasing (at a premium) a property that has been partly explored and/or developed by others; and
- Resuming the development or continuing to develop a project that the company previously initiated, but discovered it to have a high probability of low return.

A mining operation will frequently strive to verify the minimum reserve in order to recompense investment and facilitate further exploration for the subsequent phase (Seccatore *et al.,* 2014:804). Although this approach is advocated for small scale projects, the logic applies to all mining projects. All ventures strive to spend the minimum possible initially, utilising revenue (Opex or stay-in-business capital) to fund ancillary expansion.

This methodology is appealing and could lead to massive capital savings. A concern identified in the work conducted by Seccatore *et al*. (2014), relates to the potential circularity of the final formula to determine the minimum reserve required (Seccatore *et al*., 2014:806); portrayed in the representation of the formula below, in conjunction with the variable descriptions within Table 2-4:

$$V_{R,Min} = \frac{M + S + P + V + E + MO + MD + PROFIT}{\eta_M \left[\left(\frac{g_N}{\eta_D}\right) \times \eta_R \times p - C_M - C_P - C_A\right] - C_E \times OF}$$

Table 2-4: Variables for Minimum Reserve Formula (adapted from Seccatore *et al.*, 2014:806)

VARIABLE	DESCRIPTION	VARIABLE	DESCRIPTION	VARIABLE	DESCRIPTION
$\boldsymbol{V_{R,Min}}$=	Volume of Proved Reserve - Minimum	S=	Infrastructure	P=	Plant
$\boldsymbol{M}$=	Equipment	E=	Engineering	MO=	Mine Opening
$\boldsymbol{V}$=	Services	$PROFIT$=	Profit	η_M=	Mining Recovery
$\boldsymbol{MD}$=	Mine Development	η_D=	Mining Dilution	η_R=	Processing Recovery
$\mathbf{g}_N$=	Natural Mineral Grade	C_M=	Cost of Mining	C_P=	Cost of Processing
$\boldsymbol{p}$=	Price of Mineral Product	C_E=	Cost of Exploration	OF=	Operating Factor
$\mathbf{C}_A$=	Additional Costs				

The resultant formula incorporates all the required fields for calculating final profitability; the employment of which makes it almost impossible to establish the minimum reserve ($V_{R,Min}$) requisite, without initialising exploration services. The exploration cost (C_E) is necessary to ascertain the volume of proven reserve required (V_R). This extrapolates into a major challenge, as the entire premise of the study is to determine what capital is needed to instigate the operation. Figure 2-9 delineates a visualisation of Seccatore *et al.*'s (2014:806) proposed replication cycle.

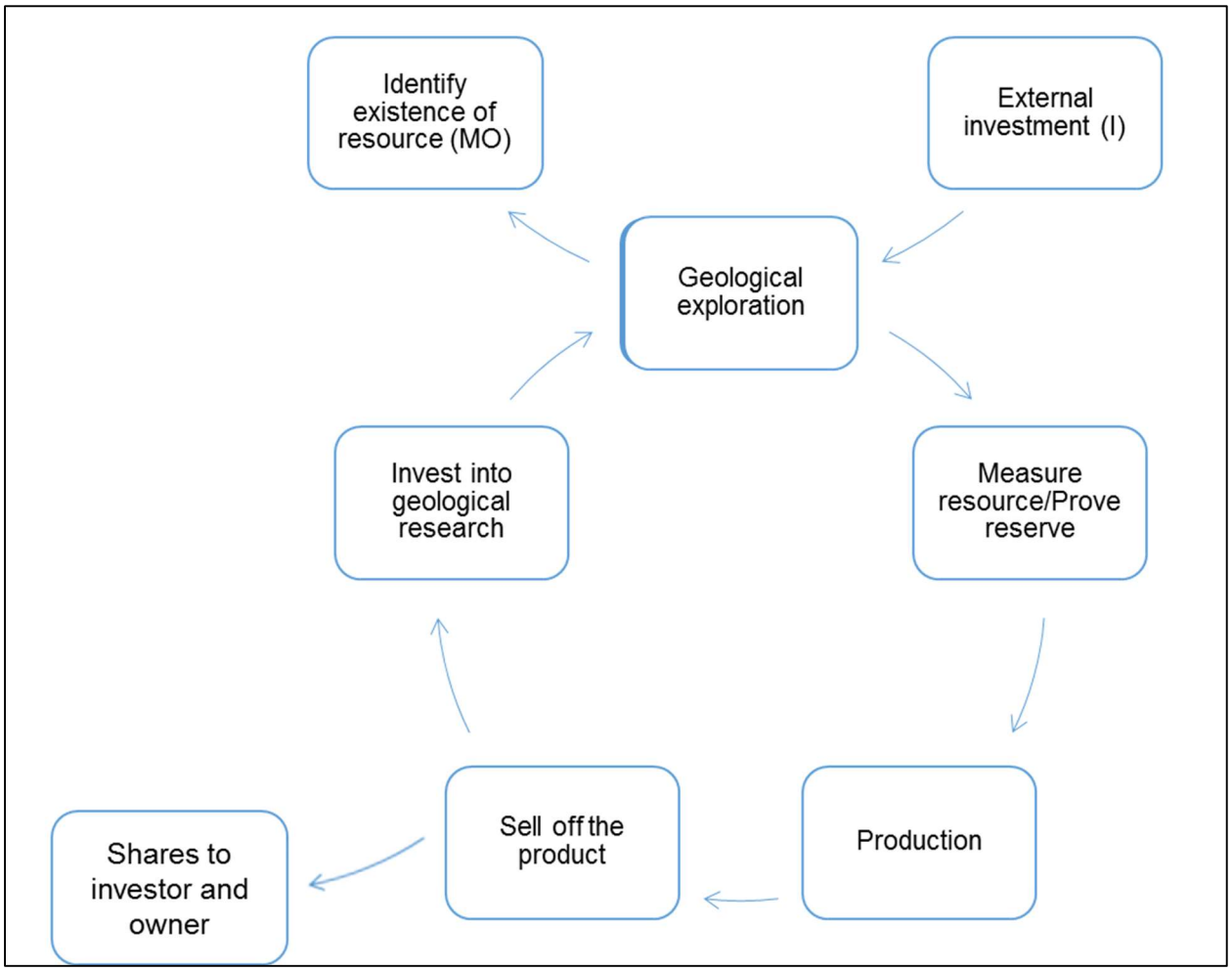

Figure 2-9: Proposed Method of Replication for Reserve Declaration (Seccatore *et al.*, 2014:806)

The preceding figure endeavours to resolve the issue raised apropos the formula. There is a preliminary identification of resource, along with initial external investment. Within this approach it is implicit that there is initial up-front capital available with which to conduct exploration work. In this form the approach can be appealing to all scales of mining. If implemented correctly this method allows for minimal external investment, with consequently, greater profits for the mining company.

As the method is not clear and concise, an alternate approach is also investigated.

2.6.2 Resource-to-reserve guideline

The research previously emphasised that different individuals (or even dissimilar circumstances or scenarios) will invariably arrive at contrasting reserve estimates. Further to this, there exists an auditability concern *vis-à-vis* the resource-to-reserve process. It is virtually unattainable to

replicate the work of another person without knowing exactly what steps were followed and factors applied. This section outlines an approach that has the potential to create a basic template for resource-to-reserve estimation.

Diering *et al.* (2012:557) contends that, generally, the adopted approach comprises the geology and surveying departments conducting the declaration of resources and reserves. The geologist pronounces the resource and the surveyor applies modifying factors to the proclaimed resource for mining and derives the reserve.

At Anglo American Platinum the reserve declaration is seen as an outcome of their business plan. The intention is to derive an approach that would enhance efficacy and reliability, in consort with facilitating the reproduction of the results. The proposed process is an endeavour to establish a true, global best practice for the reporting of resources and reserves, which is cross-functional in application. The Basic Resource Equation (BRE) and the Basic Resource to Reserve Equation (BR2RE) were developed for this objective. The basis of the modus is to simplify the modifying factors into dilution and losses. A crucial aspect of the process is adherence to the SAMREC Code. Consequently, particular areas are defined as 'pre-resource' and are not included in public reporting. The utilisation of BRE leads to complete and refined accounting. Owing to the alterations, determining resources and reserves are transferred into the domain of the mineral resource management discipline (Diering *et al.,* 2012:557-558). The core concepts correlate well with the undertakings of Winterstetter *et al.* (2015) and Weatherstone (2005), who advocates that a multi-skilled team (CP team) should be responsible for the derivation of the reserve, rather than a single CP.

Diering *et al*. (2012:558), significantly, assert that the reserve is a product of the business planning cycle, which includes all aspects, for instance mine extraction strategy and short term planning. Their broad outline of the yearly planning process is explicated in the ensuing points.

1. The creation and review of a mine extraction strategy for the mining rights area;

2. The development and appraisal of a production profile for a three-year budget period;

3. The formation and assessment of an operation labour proposal for a three year budget period;

4. The construction and consideration of operating cost and capital estimates for the budget period;

5. The establishment and evaluation of the production profile for the LOM plan (year four onwards);

6. The design and examination of a LOM labour strategy;

7. The development and review of Opex and capital estimates for the LOM; and

8. The reconciliation and declaration of resources and reserves associated with the business plan (Diering *et al*., 2012:559).

The process describes an easy-to-use guide that can be replicated whenever needed. To uphold good practice and ensure quality results regular reviews are conducted across multiple disciplines. For planning purposes different levels of confidence intervals are utilised, as depicted in Table 2-5.

Table 2-5: Level of Confidence Classification Intervals (adapted from Diering *et al.*, 2012:559-560)

LEVEL	DESCRIPTION
Level 1	Existing operations - no project capital required (stay-in-business capital)
Level 1e	Approved capital projects which are being executed (expansion/replacement projects)
Level 2a	Feasibility study level with capital estimates within ± 10% accuracy
Level 2b	Pre-feasibility study level with capital estimates within ± 15% accuracy
Level 2c	Conceptual study level with capital estimates within ± 25% accuracy
Level 3	Scoping study level with capital estimates within ± 30% accuracy
Not in business plan - NIB (Eng)	Uneconomic areas that may have been subject to extensive study work through to pre-feasibility level, but are uneconomic for current long-term planning parameters
Not in business plan - NIB (Nw)	Areas that have not been studied for exploitation and is not planned for well into the future (>30 years)

In practice, these intervals have approximate interactions, as portrayed in Figure 2-10. Within this representation the direction of mining progresses in a downward direction. It is apparent that the further one moves away from the blue (mined out) area, the lower the confidence intervals encountered.

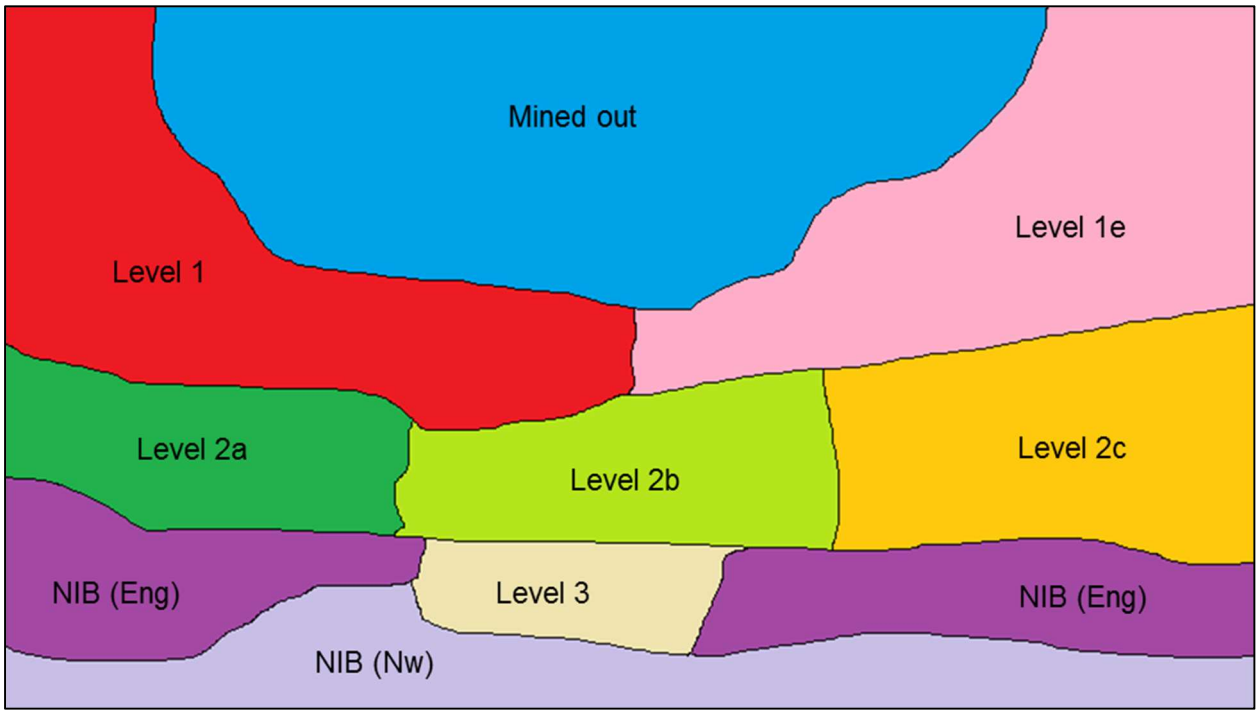

Figure 2-10: Level of Confidence Interaction (adapted from Diering *et al.,* 2012:561)

This exemplification is advantageous for the coarse determination of where the different intervals are, in relation to current mining operations, as well as potentially facilitating the establishment of areas that should be investigated earlier than initially anticipated. With regard to production planning, it is deemed that a time based profile of the connections and associations of these intervals is of greater functional and practical utility. Figure 2-11 demarcates an interpretation of the different confidence level areas over LOM.

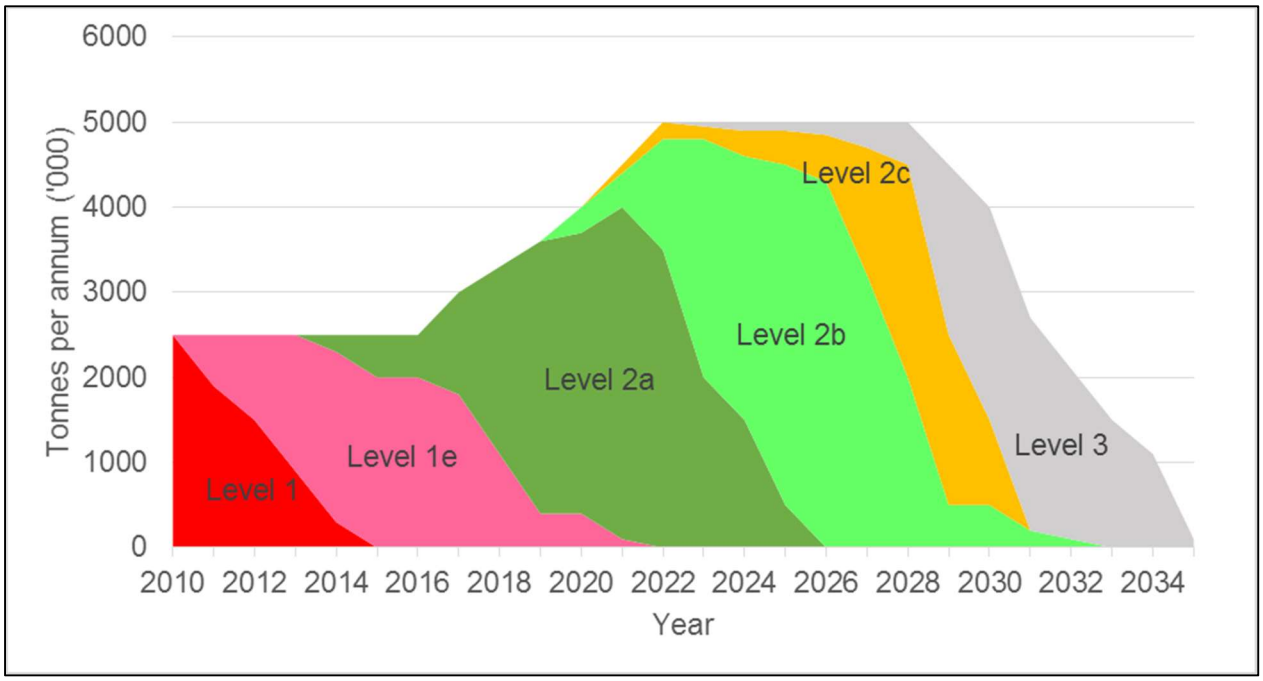

Figure 2-11: LOM for Level of Confidence Areas (adapted from Diering *et al.*, 2012:562)

From Figure 2-11 it is far easier to observe the incorporation of the different areas and confidence levels into the proposed mine plan. The depicted example clearly illustrates that only Levels 1 and 1e are mined in the first three years, thus complying with the process previously presented. Diering *et al.* (2012:561) maintain that this approach, in addition, assists in ascertaining the necessary ramp-ups and proportions required per confidence interval level. An example of a production ramp-up is outlined between 2016 and 2022 (from 2.5 Mt/yr to 5 Mt/yr). A ramp-up can be due to various factors, for instance the need to produce more mineral product or as a result of a decrease in mineral grade.

Diering *et al.* (2012:562) define a reserve in accordance with the SAMREC Code (see definition in *1.1 – Introduction*). Corresponding to these pundits' revised approach, the definitions of the confidence intervals at Levels 2a and 1/1e are deemed reserve, with the inclusion of Level 2b, where there is a high probability of the area being studied in more detail within the next planning cycle.

In order to facilitate an enhanced comprehension of the progression from resource to reserve, in consort with improving resource utilisation, ameliorating the accuracy of reporting and developing the precision of reconciliation, Diering *et al*. (2012:563-564) emphasise certain key definitions, which are expanded and explicated below.

Process

- Reserves are based on a scheduled resource, ensuring that the planning discipline is integral to the process;
- Appropriate mine design and layouts are applied to the resource areas, as decreed by current mining methods and mine design criteria, to derive a mineable resource;
- The mineable resource is scheduled, in accordance with production requirements, to develop a scheduled resource;
- Only current operations (Level 1), approved projects in execution (Level 1e) and projects in the feasibility study phase (Level 2a), included in the business plan, are defined as reserves (in Proved and Probable categories, as per the SAMREC Code);
- The remaining scheduled area of the LOM plan comprises the scheduled exclusive resource and includes projects from Levels 2b, 2c, and 3, with the objective of optimally extracting the available resources;
- Resource categories have been increased to cater for exclusions and confidence levels (e.g. resources above the geothermal gradient cut-off are transferred to mineral inventory);
- The introduction of mining losses pertaining to resources left in pillars (specific to underground mining), the mineable resource excludes material segregated in mine design-related pillars;
- Uneconomic production plan ‘tails’ revert to resource or mineral inventory (depending on the specific position in the mine plan), through a ‘tails management’ process;
- The scheduled reserves are multi-discipline peer-reviewed and officially approved by the CP(s); and
- The application of modifying factors (as per the SAMREC Code) is implemented, in three distinct phases:
    - Mine Design and Scheduling: Comprises the modifying factors that impact on dilution of the resource (i.e. stope width versus resource width, tertiary development and other waste mining done on the reef horizon etc.) and modifying factors that define mining losses (e.g. non-mineable pillars), which are applied to the criteria included in establishment of the mine design and scheduling;

- Processing: Constitutes the modifying factors that influence the efficiency of processing and recovery, which are applied to the scheduled resource, with a resultant mineable reserve; and

- Economic: The subsequent application of modifying factors that influence the economic aspects of the mining operation, producing the tails management requirement.

Reporting

- Resources are declared inclusive and exclusive of reserves.

Reconciliation

- The reserve definition process is readily auditable;

- Reconciliation between the Level 2a plan and declared reserves is possible; and

- Resolution between declared reserves and scheduled resources converted to reserve is achievable.

With all the requisite definitions and explanations concluded, the BRE and BR2RE may now be discussed. These equations, were constructed by Diering *et al.* (2012:566), from first principles (simplest components), subsequently utilising them to track and record the progression from pre-resource to reserve.

As is good practice Diering *et al.* (2012:570) conduct reconciliations (in this instance, between CADSMine and Datamine results). Both Datamine and CADSMine are specialised mining software packages. Figure 2-12 portrays the resolution and conciliation approach, with Datamine on the left and CADSMine on the right.

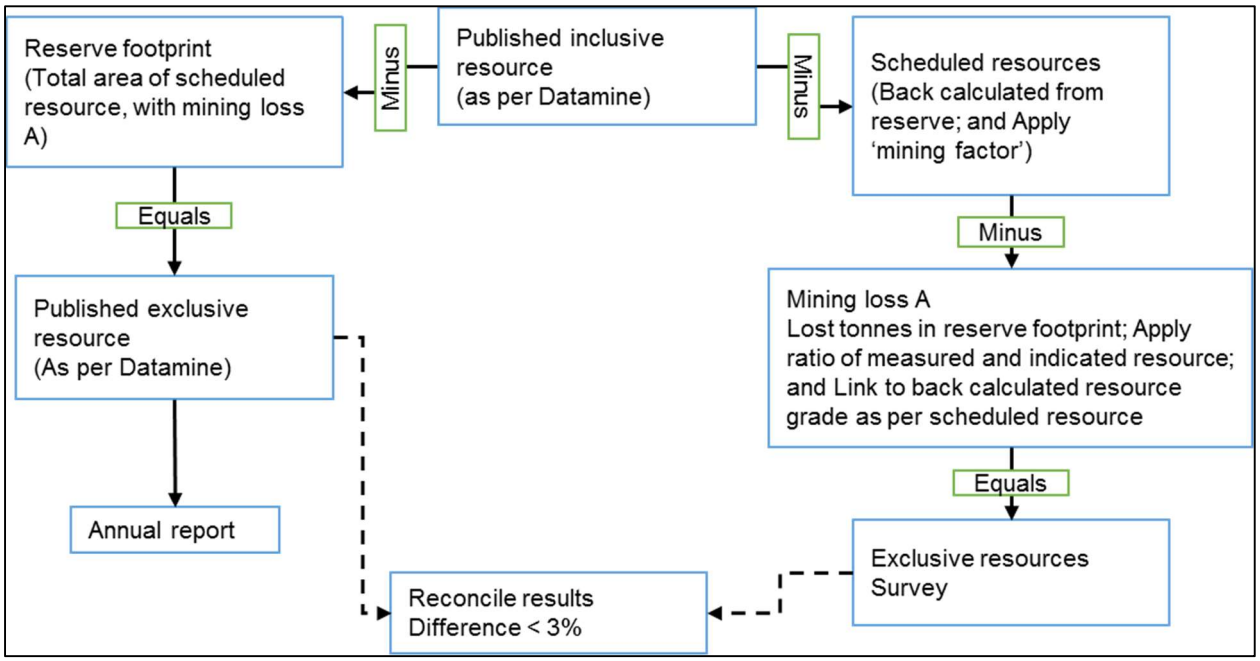

Figure 2-12: Reconciliation Approach Applied to Resource (adapted from Diering *et al.*, 2012:570)

The figure illustrates how both processes originate from the 'published inclusive resource', which is displayed at the top, in the centre. From this point the Datamine process flows down on the left and the CADSMine process descends progressively on the right. The two processes need to reconcile to within 3% of each other, termed the 'reconcile results difference', at the bottom. The Annual Report is derived from the Datamine work conducted. The logic and flow of the reconciliation is based on the rationality followed in the BRE. Thus, the use of the BRE and BR2RE are deemed appropriate tools for consolidating and resolving, rendering the resource-to-reserve process transparent and auditable.

The application of a correction factor is not considered good practice, frequently designated, or referred to, as a 'mine call factor' or 'mining factor'. The mine call factor is often described as a ratio, expressed as a percentage, comprising the proportion of the quantity recovered compared with the estimated quantity based on sampling (Harmony, 2010). Stated alternatively, the mining factor is a fraction illustrating the variance between what was expected versus what has been extracted. Furthermore, this mining factor is applied to the remaining resource, in an attempt to better reflect the quantity left in the ground. Diering *et al.* (2012:567) evince factors ranging between 96.82% and 101.93% in use for the BRE. However, for the BR2RE, the value is fixed at 100%. It is deemed as better practice to review and sequence the modifying factors applied to the resource, determining which require updating or adjustment.

The process set forth by Diering *et al*. (2012) is uncomplicated and straightforward to conduct, and includes most (if not all) relevant modifying factors, albeit specifically designed for platinum. The three distinct modifying factor groups (mine design and scheduling, processing and economic) and the auditability of the procedure are identified as the critical, fundamental concepts to implement during the resource-to-reserve process. Having identified and clarified a basic approach to a resource-to-reserve model, the following section will investigate, in greater detail, the financial aspects.

2.7 Financial uncertainty

In an attempt to resolve the issues associated with uncertainties and discrepancies in valuation methods, the South African Code for the Reporting of Mineral Asset Valuation (SAMVAL Code) was officially launched in April 2008 (Samcode, 2015). The primary intent of the Code is to expound and introduce clear definitions of principal terms, along with providing guidance apropos the valuation process.

Macfarlane (2002:45) asserts that the DCF is a prominent method utilised during the valuation of a mining project. Adding the DCF values facilitates the calculation of the NPV. Sayadi *et al*. (2014:1067) contend that NPV estimations are formulated under uncertain conditions. Despite this, these estimates constitute the basis of reporting to corporate investors, local communities, government, etc. A recognised, major concern comprises the lack of certainty pertaining to economic factors (Evatt *et al*., 2012:340).

The major risk components in financial uncertainty are attributed to commodity price variations and errors in estimated ore grade, both external factors to the resource-to-reserve process. Alterations in these parameters have the potential to result in large profits for certain mines; conversely, however, fluctuations therein can cause mines to suffer great losses, possibly with resultant closure. In an attempt to counter this, abandonment options have been studied by Brennan and Schwartz, extending back to 1985 (Evatt *et al*., 2011:244-245).

This uncertainty is not due to a lack of research or necessity, as evinced in a 10 year North American operations study, which revealed the declining gold price as constituting the single greatest cause of mine closure. Additionally, the diminishing gold price has been identified as a critical component for declared reserve estimation. The principal issue associated with this pertains to reserve estimates manifesting variations, as a result of economic interpretation and alterations in economic inputs, over the entire duration of the project. This uncertainty engenders the potential distinction between probable and proved reserves (see section *2.3 – SAMREC*), which are impacted by estimate confidence levels. The JORC Code makes provision for the inclusion of the conviction in the estimate, via error bars or statistical quartiles. Yet, methodologies

to take economic uncertainty into account are still sparse (Evatt *et al*., 2012:340-341). Macfarlane (2002:47) categorises acceptable accuracy levels, as depicted in Table 2-6.

Table 2-6: Accuracy Levels Commonly Accepted for Different Valuation Stages (Macfarlane, 2002:47)

TYPE OF STUDY	ACCURACY OF CAPITAL COST ESTIMATES	ENGINEERING COMPLETED	SUITABILITY OF DCF METHODOLOGIES
Exploration Review	50%	Nil	No
Order of Magnitude Study	40%	2 – 3%	Generally Yes
Advanced Exploration Study	20 – 40%	3 – 10%	Yes
Pre-Feasibility Study	20%	10%	Yes
Feasibility Study	10%	30%	Yes
Job Control Estimates	5%	50 – 70%	Yes

As the table illustrates, estimates at different study levels have diverse margins of error. In order to minimise the risk associated with cost estimates, contingency costs are added. These contingency costs are dependent on the certainty associated with the input values (Rendu, 2002:128). The issue is that an estimate incorporating the upper extreme of the variation (i.e. the total estimate plus the additional estimate percentage) may engender the total cost too high, thus resulting in the termination of the project. For example, 'exploration review' makes provision for 50% accuracy. This is to allow for factors which could not be studied sufficiently and might incur additional costs. Thus, if the estimate is $ 500 million, the accuracy factor would require a budgeted cost of $ 750 million, which is significantly higher and could cause the project to fail, prior to further detailed investigation. Rendu (2002:128-129) avers that contingencies that are too high have the potential to terminate the continuation of a venture; conversely, if the contingencies are too low the ensuing operation may have financial shortages. The approach commonly utilised in practice comprises selecting the option of expending additional funds during upfront engineering, rather than incorporating the risk of unforeseen expenses in the course of construction or operation. Typically, a trade-off occurs between Capex and Opex, with the norm constituting an inverse relationship between these expenditures. This denotes that there is a balance that must be reached for optimal performance. Higher Capex will exert additional financial strain on the project during start-up, but will allow the project to be less reliant on unknown future

commodity prices. Lower Capex will be beneficial in the short term, but adds to the uncertainty regarding forthcoming commodity values.

Evatt *et al*. (2012:341) assert that there have been advances *vis-à-vis* methodologies taking economic uncertainty into account. These procedures emphasise an adaptive or responsive operating system, which allows the calculation of cost saving measures for the potential event of abandoning the operation if commodity prices decline too much. This contrasts with deterministic operating systems, which force calculations over the entire life of the project. The Feynman-Kac equation (abandonment approach) is considered to engender a distinct advantage over hedging arguments (deterministic approach). A particularly powerful ability of the equation is the ability to generalise, whereby a broad range of expectations are taken into consideration, rather than valuation exclusively. This expansion of facets includes the probability of a project being completed, as well as determining the duration of the venture.

In their study, Evatt *et al*. (2012:341-342) focus on a single economic factor, viz. the commodity price; due to it being exogenous and independent, i.e. not within the mining company's sphere of influence. Coupled with the economic factor of price, is the economic cut-off grade (the cut-off grade refers to the lowest grade of ore that can be economically extracted), as the latter is determined by a fixed commodity price. This research study requires the calculation of two expectations. The initial relates to the final reserve that will be extracted (not considering price uncertainty). The second is the probability of completing the project. The probability of completion acts as a measure of confidence in the reserve size estimate and can be graphically represented (with a box and whisker plot). An example of the results obtained thereby, is exhibited in Figure 2-13. This example studies resource extraction, while the pre-calculated exit-price level is kept constant.

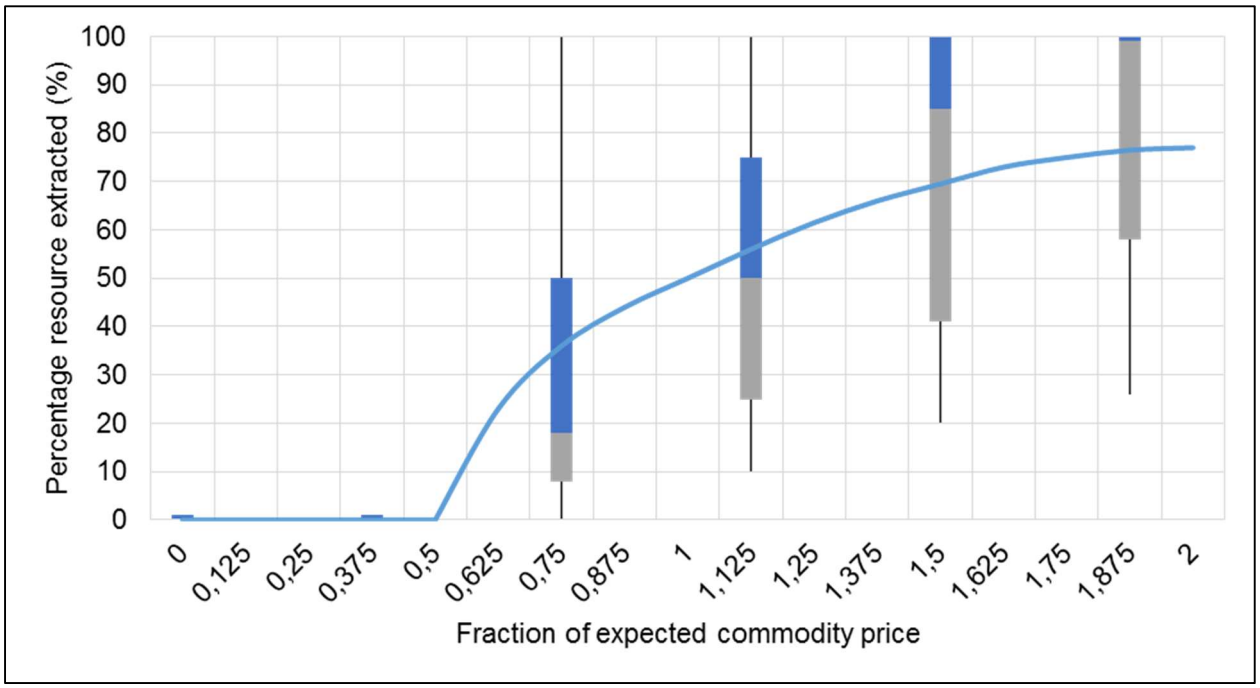

Figure 2-13: Expected Extracted Reserve Size, with Box and Whisker Plot as Measured Against a Normalised Commodity Price (adapted from Evatt *et al*., 2012:343)

In the preceding figure it can be observed that the exit-price has been fixed at 0.51 (51%) of the normal/expected commodity price, at which the project is studied (blue line on the graph). As soon as 51% is exceeded there is the possibility of partial extraction of the resource. For this exemplar, a value equal to double the study price (2 on the x-axis) would allow for almost 80% of the resource to be extracted (or converted to reserve). The box and whisker plot shows the spread of risk, with the ends of the whiskers representing 5% and 95%, the ends of the boxes 25% and 75% and the split in colour the 50% median. Toward the lower end of the scale (left on the x-axis), the spread of risk is unfavourable and at high ore prices the risk decreases. For instance, at a 75% commodity price and 75% risk, the extraction would be approximately 50%. Alternatively, at a commodity price of 150% and 25% risk, the extraction would be around 40%. The inference is that a higher extraction is possible at a lower commodity price, as long as greater risk is accepted, serially indicating the lower probability of project shutdown when ore prices are higher (Evatt *et al*., 2012:343).

In addition, Evatt *et al*. (2012:343) conducted an investigation into the impact of price volatility and changes to the resource size. This is summarised in the succeeding points.

- Price Volatility: Results confirmed that a higher volatility conduces lower expected resource extraction; and

- Resource Size: Findings corroborate that a larger resource would add to the risk of price decline, consequently engendering a lower extraction rate, despite an increase in the total tonnes extracted.

In their research, Evatt *et al.* (2012:344), assert that cut-off grade changes or unfavourable commodity prices can lead to alterations in the quantity of ore that will be extracted prior to closure. Weijermars (2015:12) maintains that an evaluation based on cut-off grade analysis (as most projects are) has the inherent risk that a drop in commodity price necessitates higher grade ore to meet the pre-determined economic cut-off, with a resultant, effective decrease in the reserve.

Furthermore, uncertainty is evident during the cash flow analysis process. Morley *et al*. (1999:293) categorise the customary stages in a cash flow analysis as resource and reserve; revenue and commodity price; Capex and Opex; discount rate; and NPV. These phases are portrayed in Figure 2-14, comprising the five blocks to the right.

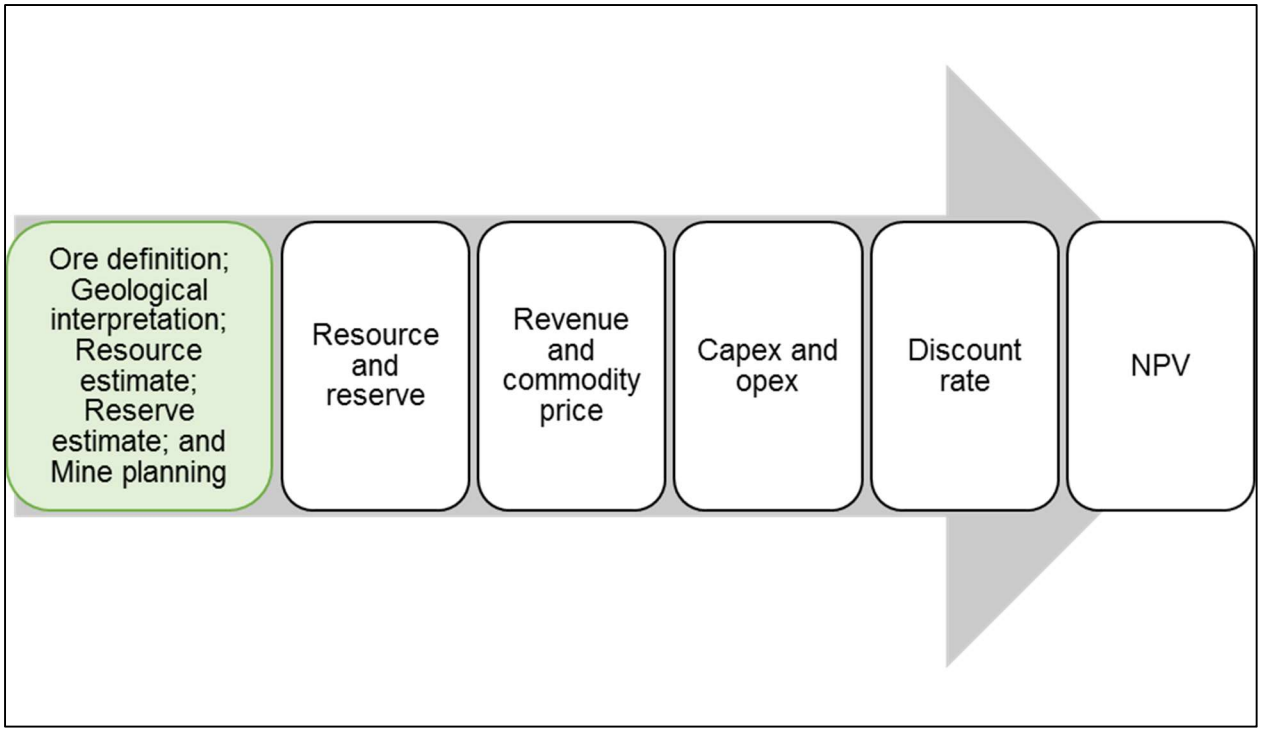

Figure 2-14: Stages in Cash Flow Analysis (Morley *et al*., 1999:293)

The first block (highlighted in green) depicts the additional process required to ensure accurate cash flow analysis. This block represents a flow of its own, viz. ore definition; geological interpretation; resource estimate; reserve estimate; and mine planning. The flow in this block

correlates well with the impetus discussed in Figure 2-2. Consequently, the resource-to-reserve process and financial modelling are identified as interrelated processes.

This section identified, as two core variables, inextricably connected, cut-off grade and commodity price, with the major issue comprising that neither can be controlled. The use of adaptive/responsive methods is mentioned; however will not be employed within this study. An additional node was identified as necessary, to the cash flow analysis procedure, to facilitate greater clarity pertaining to calculations, effectively constituting the resource-to-reserve process. The subsequent section will investigate the financial indicators most applicable for analysing the viability of a mining project.

2.8 Financial indicators

The primary financial indicators typically comprise capital requirements and NPV. These indicators are reliant on the information provided, which has formerly accounted for certain risk. The norm is to employ a deterministic approach for the base case and, if the indicators provided satisfy the decision makers' criteria, they may approve the project for further study. The core assumption is that the contingencies taken into account by the various specialists are sufficient to accommodate any challenges that may arise (Rendu, 2002:123); although in the foregoing text this was discussed and deemed a risky assumption. Sayadi *et al*. (2014:1067) contend that investment projects typically entail DCF analysis (a summation of which renders NPV). Other financial indicators include, *inter alia*, IRR; and payback period. NPV is the preferred financial indicator.

The research evinces that the most trusted measure is NPV. Financial indicators are very rarely the only factors to consider and the subsequent section considers alternate potentially significant indicators.

2.9 Other indicators

Rendu (2002:124) cautions against the exclusive utilisation of financial indicators in the assessment of a project, as they frequently exclude other valuable gauges. These alternate criteria include. *Inter alia*, commodity volume extracted; environmental impact; project location; and available expertise. For instance, reclamation cost has a very low NPV, but can have a significant long term impact on the environment, post-project.

Moreover, political factors need to be contemplated. Rendu (2002:131-132) identifies certain political risks, which are outlined in the following points.

- Currency conversion rate;

- Expropriation or creeping expropriation, which has been a major issue in Zimbabwe and is a looming concern in South Africa;
- Political violence, which may be general or targeted toward a company; and
- Unilateral changes in laws and regulations.

These political risks are unavoidable, but can be managed and/or avoided by means of correct and strategic tactical planning. It is difficult to truly quantify political risk and within this research none of these 'non-financial' indicators will be considered. The following section investigates sensitivity analysis, a manner by which to measure the impact of these various, diverse facets and factors.

2.10 Sensitivity analysis

The basis of a sensitivity analysis is to alter one or more key parameters, in a predetermined range, measuring the modification in the resulting output. The custom is to vary a single parameter at a time, to avoid complex situations that might arise. The range, by which a facet is adjusted when conducting the sensitivity analysis, is a function of the confidence in the parameter (note the case discussed in Figure 2-13, with the box-and-whisker plots). The exercise is not undertaken to determine the likelihood that the parameter will be a specific value, rather the parameters typically subject to sensitivity analysis are those perceived to alter and significantly impact the project's financial viability. Particular possible parameters include tonnage; grade; commodity price; recovery percentages; and Capex and Opex. Upon conclusion of the analysis of various parameters it is possible to determine which modifying factors are the 'controlling parameters'. These are the factors that most significantly impact the project value and financial viability. This analysis can, in addition, assist in ascertaining the critical point, per parameter, at which the economics of the project deteriorate to unacceptable levels (Rendu, 2002:124). Figure 1-2 (in section *1.5.2 – Empirical study*) demarcates what a characteristic sensitivity analysis reveals.

Sayadi *et al*. (2014:1067) discuss the utilisation of sensitivity analysis to determine NPV, wherein the factors that affect project success are assessed under probable ranges. The authors explain that these ranges are determined by economic experts and although the process is repeated for each variable in isolation, the combination effect should also be understood.

Sensitivity analysis has been identified as a beneficial and advantageous instrument by which to mathematically and visually measure the impact of a single (or multiple) factors on the NPV of a venture.

2.11 Summary

From the literature review it is clearly apparent that mining project viability is dependent on multiple, diverse factors and facets, and can be calculated in many different ways. CRIRSCO and SAMREC are significant international and local standards, respectively, with the intent of providing guidance in the reporting of mineral assets. The resource-to-reserve process is identified as a critical, primary building block to eventually report on mineral assets to investors and stakeholders. From these standards, it has been determined that there is minimal guidance in this process. This is deliberate, with the objective of ensuring a CP(s) utilise his/her expert judgement and experience to make the best possible decisions. Several studies reveal that there is always a divergence between the conclusions of any two CPs, with potential resolutions constituting the employment of CP teams and the utilisation of a guiding process, which is easy to interpret, can be reconciled and is auditable. The model created by Diering *et al*. (2012) offers a framework with this capacity.

The financial model utilises the reserve as a constant (which it is not) to determine the financial viability of a mining venture. The best accepted measure to express the financial value is NPV. Sensitivity analysis is ascertained as a means by which to measure the impact of the modifying factors on the NPV. This facilitates varying a single modifying factor, with the consequent alteration in NPV analysed. The subsequent chapter applies these findings to a case study.

CHAPTER 3
CASE STUDY OF A GOLD MINE WITH SENSITIVITY ANALYSIS ON MODIFYING FACTORS

3.1 Introduction

The impact of modifying factors (as per the resource-to-reserve process), on the financial viability of a mining project, will be investigated through a case study, which is based on an open pit gold deposit. This chapter initiates by discussing the characteristics of the deposit. Secondly, a mine plan will be created for the deposit. Subsequently, the mine plan becomes the input for a financial model to determine the NPV. The final section will examines various modifying factors, by means of sensitivity analyses, evaluating and expounding the impact thereof on the project's NPV.

The initial two sections make use of the Deswik software suite. The Deswik software suite is specialised mining software to enable, *inter alia*, the effective modelling, design and scheduling of a mineral orebody. The first section comprises a review of the physical characteristics of the deposit, succeeded by a reconnaissance of the orebody properties. Thereafter, a basic mine plan is created, with the sole objective constituting full extraction of the deposit. This basic mine plan will then be utilised as an input into Microsoft (MS) Excel, wherein the majority of the mining modifying factors are applied.

The financial model will be constructed in MS Excel and will apply the economic modifying factors on an annual basis. This will enable the calculation of yearly cash flows and the eventual project NPV. The sensitivity analysis consists of two sections, viz. mining and economic. The mining modifying factors will be investigated to determine their impact on the NPV. The study of the economic modifying factors will determine whether additional, alternate factors have a significant impact on the NPV. The focus of the study will remain the mining modifying factors.

3.2 Basic background and setup

3.2.1 Orebody characteristics

The fictitious gold deposit is situated on a single property. Typically, an environmental study is conducted and this case study makes provision for environmental exclusions. Figure 3-1 depicts the property and associated environmental areas.

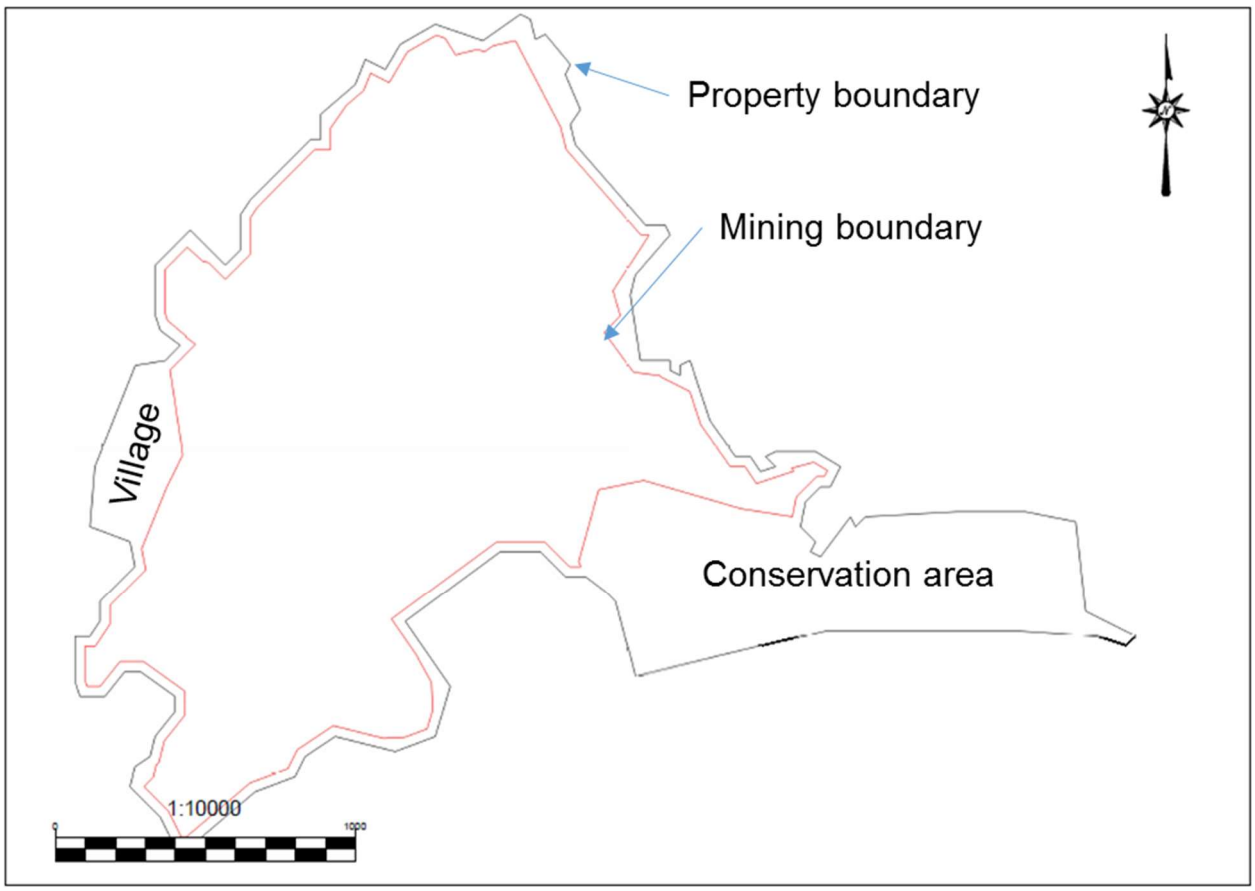

Figure 3-1: Lease- and Mineable Boundary

The orebody is confined to the lease/property boundary or outer line. The areas that cannot be mined are identified as a village to the west of the orebody and a conservation area to the east. Furthermore, there is a 100 m stand-off zone along the perimeter of the property, which is predominantly to ensure that the area outside the lease is not disturbed. Finally, no water bodies are present in the vicinity of the orebody. The area that can be extracted is indicated by the red inner line, or mining boundary.

There are three significant surfaces of importance, viz. topography, top of ore and bottom of ore. These surfaces are portrayed in Figure 3-2, Figure 3-3 and Figure 3-4, respectively.

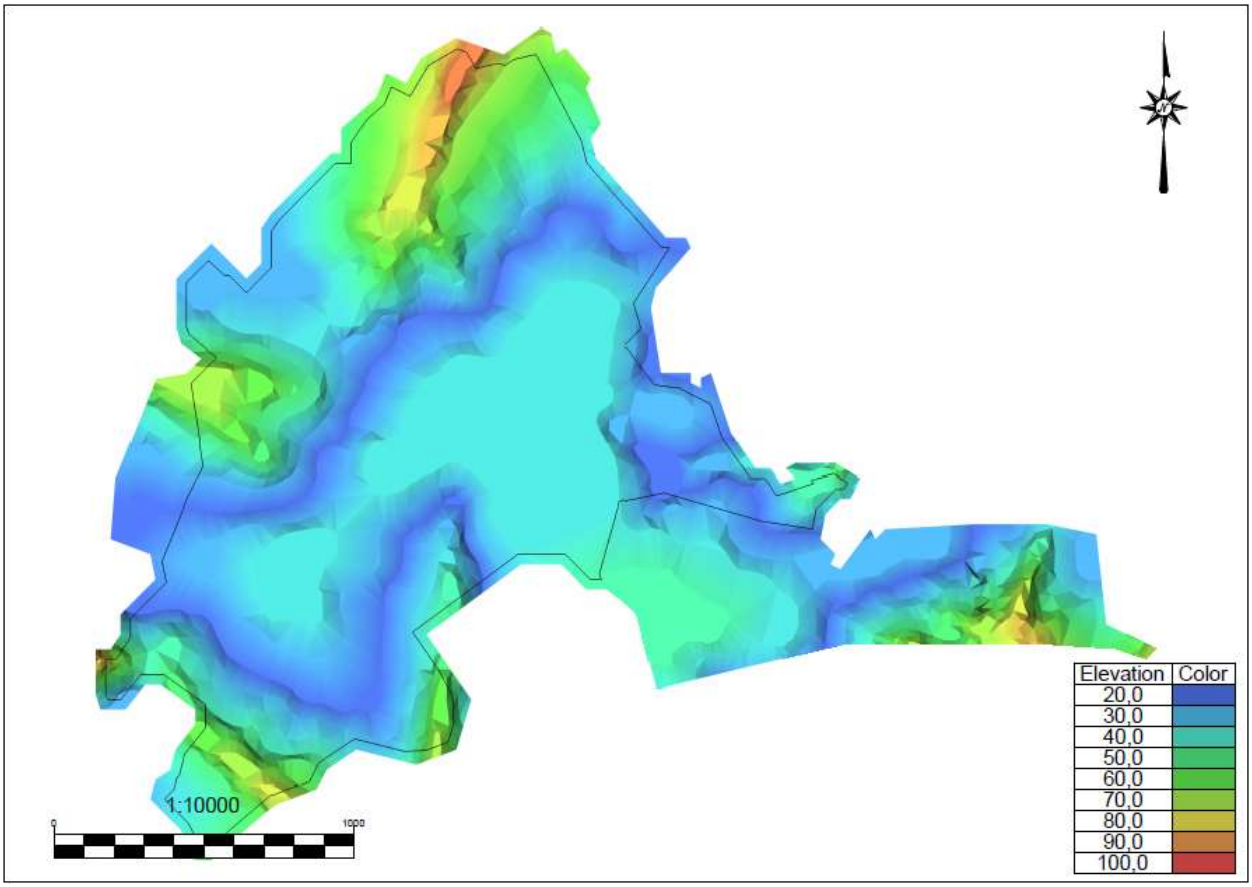

Figure 3-2: Topography

The topography has an elevation range of between 20 meters above mean sea level (mamsl) and 100 mamsl. The central area of the deposit is principally a lower lying area. The northern tip of the property has the highest elevation.

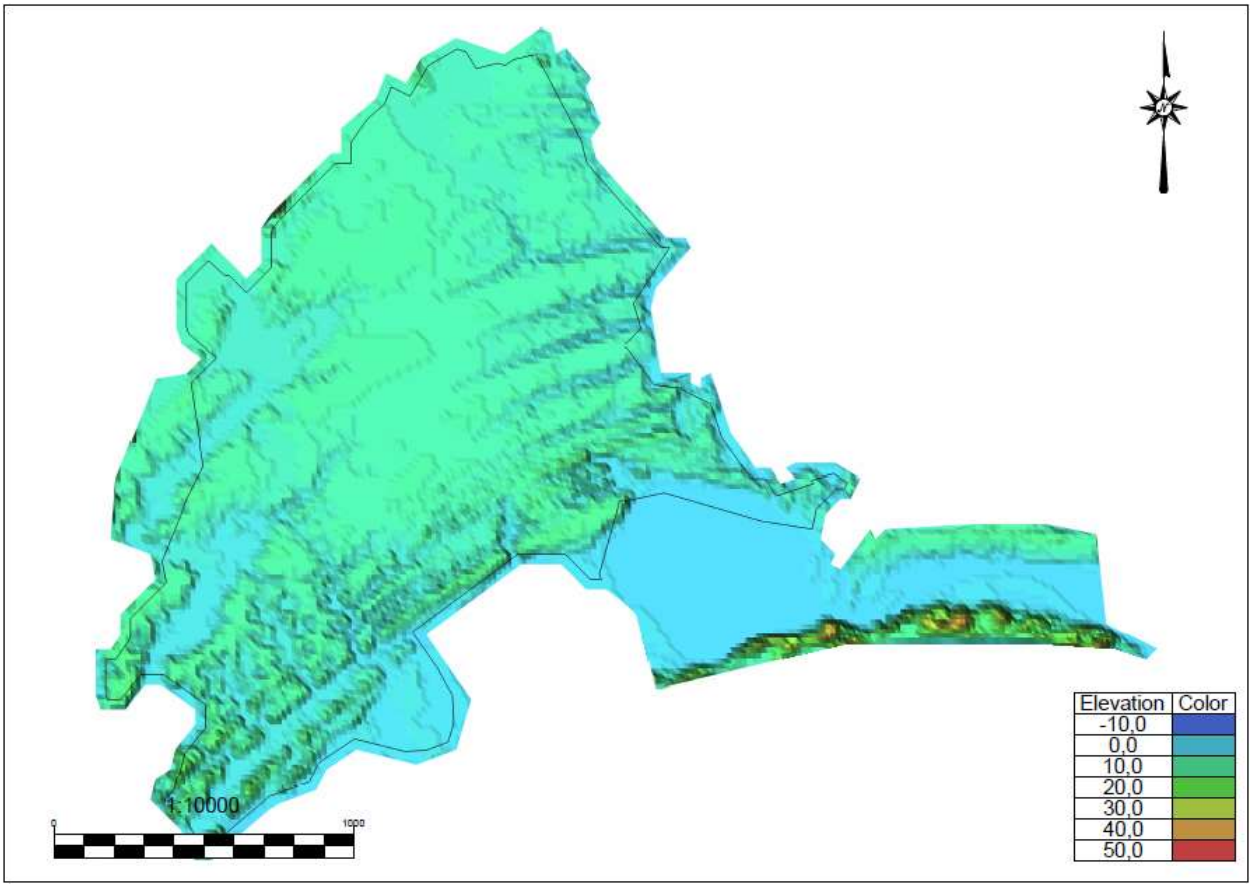

Figure 3-3: Top of Ore

The top of ore ranges between -10 mamsl and 50 mamsl. The large flat area to the east is situated in the conservation area and will not be extracted. The highest area is situated to the south of the conservation area and is also excluded. The major constituent of the area within the mineable limits is in the region of 10 to 20 mamsl. This indicates a relatively flat orebody.

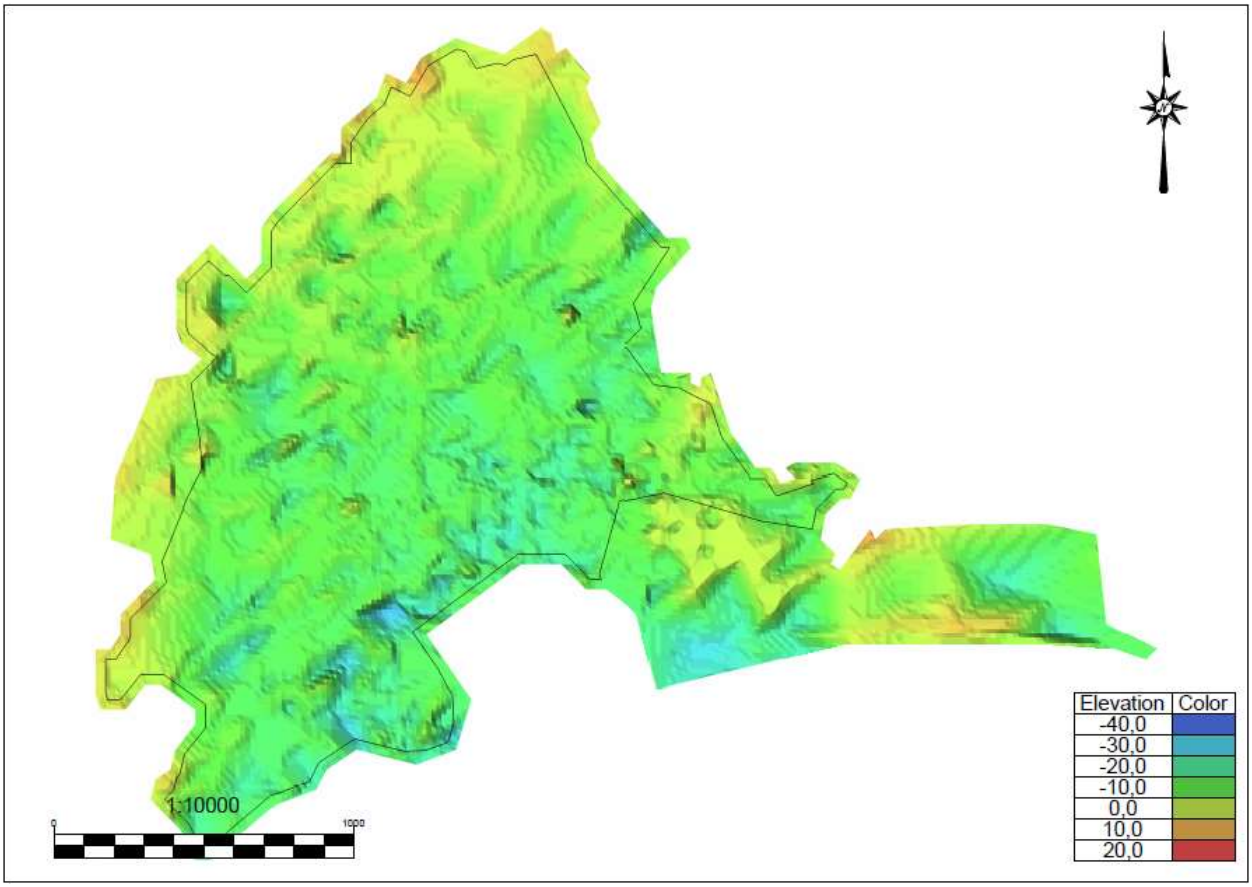

Figure 3-4: Bottom of Ore

The bottom of ore varies between -40 mamsl and 20 mamsl, with the predominance of the mineable area ranging between -30 and -10 mamsl. This, to a certain degree, flat spectrum supports the previous statement that the orebody appears to be relatively flat.

Using these three surface depictions the waste and ore material can be distinguished. Figure 3-5 and Figure 3-6 exhibit the waste and ore thickness, respectively.

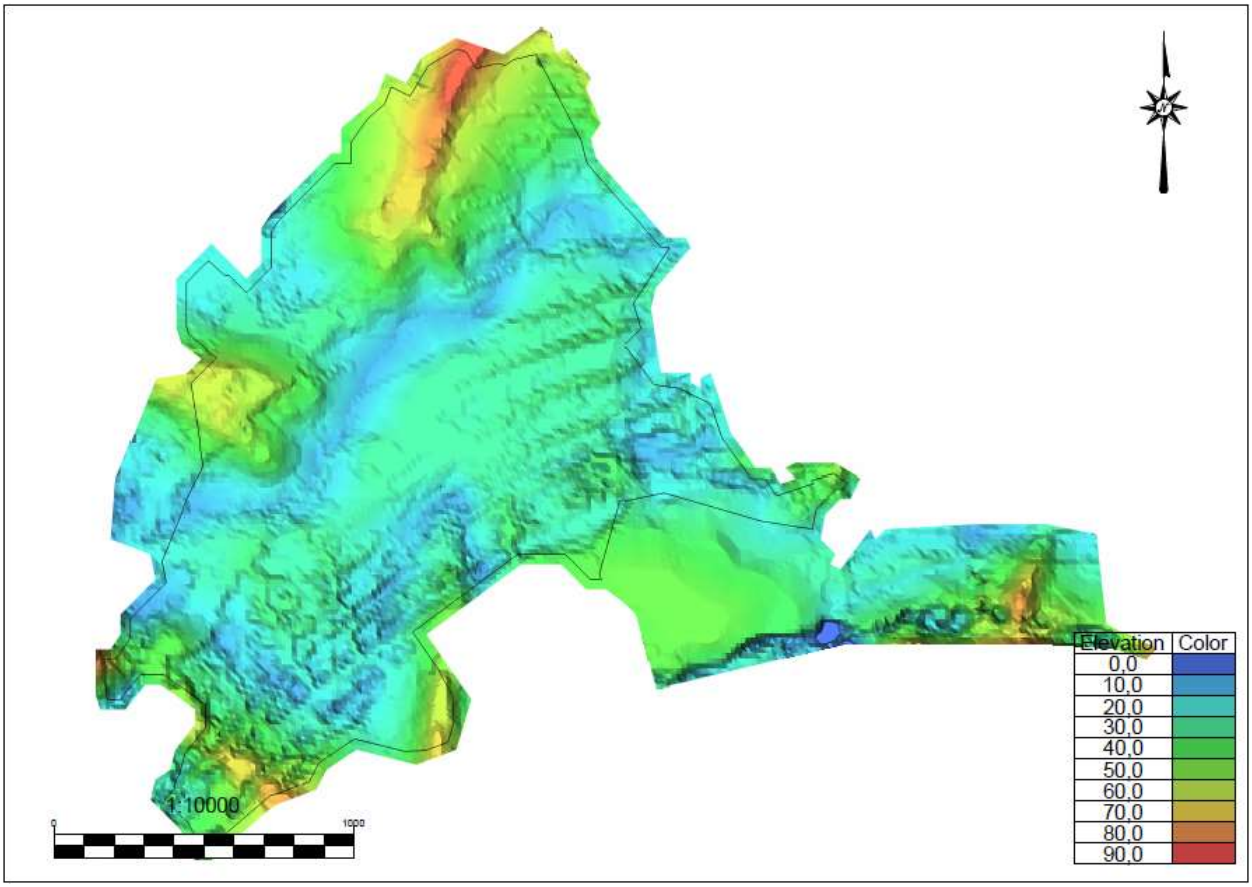

Figure 3-5: Waste Thickness

The thickness of the waste ranges between 0 m and 90 m. It is clear that the waste thickness predominantly follows the same variations as the topography. The thickest waste is situated at the northern tip of the property. The balance of the waste is comparatively flat. The waste refers to the material with no value. In an open pit mine the waste requires extraction in order to reach the ore.

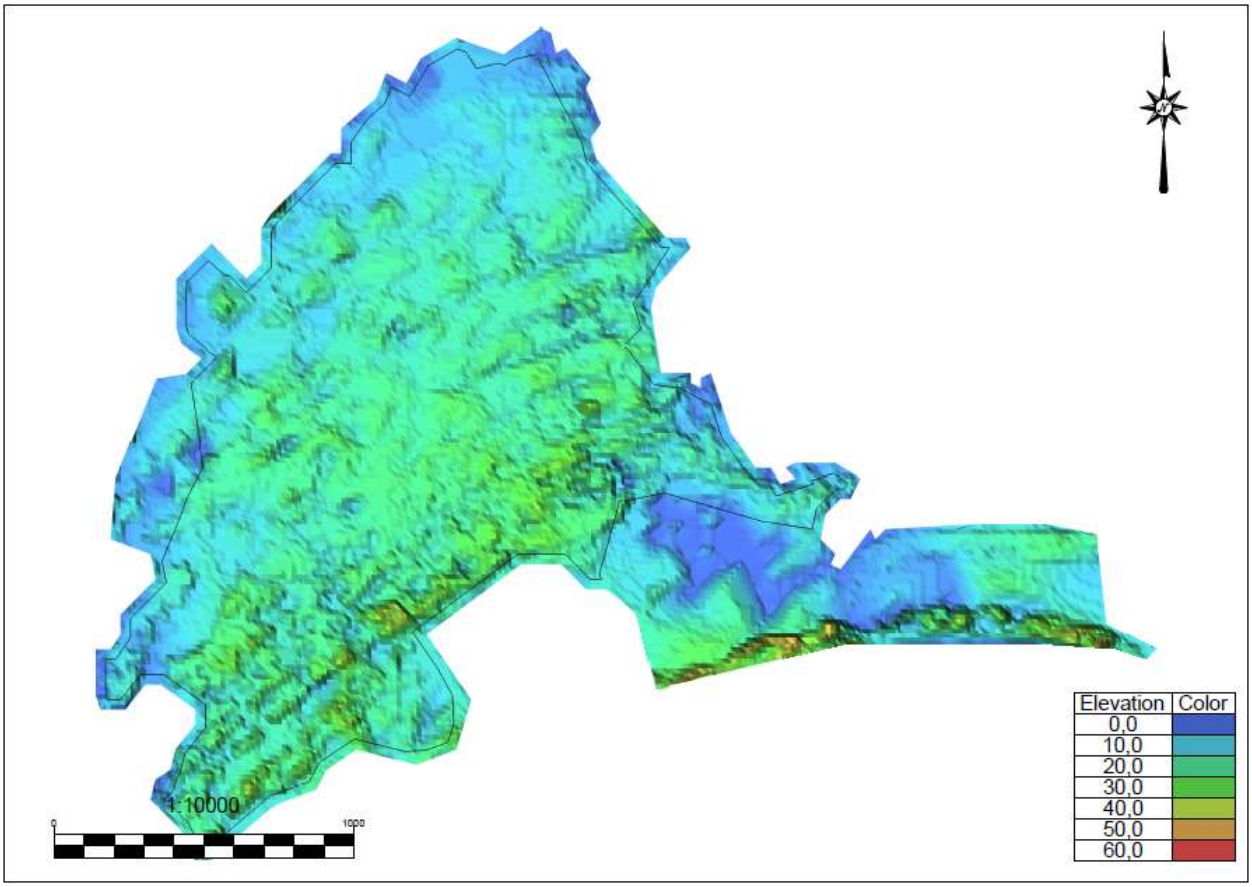

Figure 3-6: Ore Thickness

As the top of ore and bottom of ore surfaces have indicated, the orebody is reasonably flat, with a thickness of up to 60 m. From the figure, it is apparent that the orebody thins out toward the northern tip, with a thicker portion to the south. The ore is the material that contains the economic mineral(s). With the two thickness plots it appears as though the stripping ratio (ratio of waste versus ore) will increase in a northerly direction.

3.2.2 Geological model properties

A geological model refers to the model (2D or 3D) constructed with the purpose of spatially representing the ore contained within the orebody. The geological model was built to the confines of the entire lease area. For this case study, the block sizes are set at 50 m (X) x 50 m (Y) x 1.5 m (Z). Thus, the whole area under discussion is covered by blocks of these dimensions, creating a total of 168 811 blocks. The top and bottom of the geological model are as per Figure 3-3 and Figure 3-4 (top and bottom of ore). Table 3-1 expounds certain basic statistics for selected properties.

Table 3-1: Geological Model Statistics

PROPERTY	MINIMUM	MAXIMUM	RANGE	MEAN	STD DEVIA-TION	VARIANCE
Au	0.09	43.29	43.20	4.34	2.79	7.80
Ag	0.00	1.24	1.23	0.15	0.08	0.01
Hg	0.00	1.96	1.96	0.16	0.12	0.01
DENSITY	1.68	3.03	1.35	1.75	0.15	0.02

The statistics are calculated through incorporating all the blocks in the geological model. Gold (Au) varies significantly between 0.09 g/t and 43.29 g/t, constituting a total range of 43.2 g/t. This results in a standard deviation of 2.79 and a variance of 7.8. It is normal for geological models to have some outlier data. The mean for the gold content is 4.34 g/t. The silver (Ag) and lead (Hg) in the orebody are also depicted, both evincing low values. The silver and lead are not core to the study, therefore will not be further discussed. The density field displays a range of 1.35 and a mean of 1.75 t/m^3. The waste has a fixed density of 2.5 t/m^3.

The geological model is interrogated using Deswik.CAD. The following two interrogations are conducted:

- Within the property boundary (in situ); and
- Within the mining boundary (mining area).

These boundaries are as per Figure 3-1 and the results are shown in Table 3-2.

Table 3-2: Geological Model Interrogation

FIELD	INTERROGATE – IN SITU	INTERROGATE - MINING AREA
Gold (g/t)	4.36	4.21
Silver (g/t)	0.15	0.14
Lead (g/t)	0.16	0.16
Density (t/m^3)	1.76	1.76
Volume (m^3)	621 235 239	483 898 248
Tonnes (t)	1 085 300 294	845 121 885
Gold Content (t)	4 732	3 556
Gold Content (koz)	152 134	114 337

In situ refers to the total ore contained underground, in an undisturbed state. The interrogation of the geological model shows that there is an initial orebody of 1 085 Mt, with a gold content of 152 Moz. This is the in situ content and reflects the geologist's perception of total ore available. The grade tonnage curve for the entire deposit (in situ) is represented in Figure 3-7.

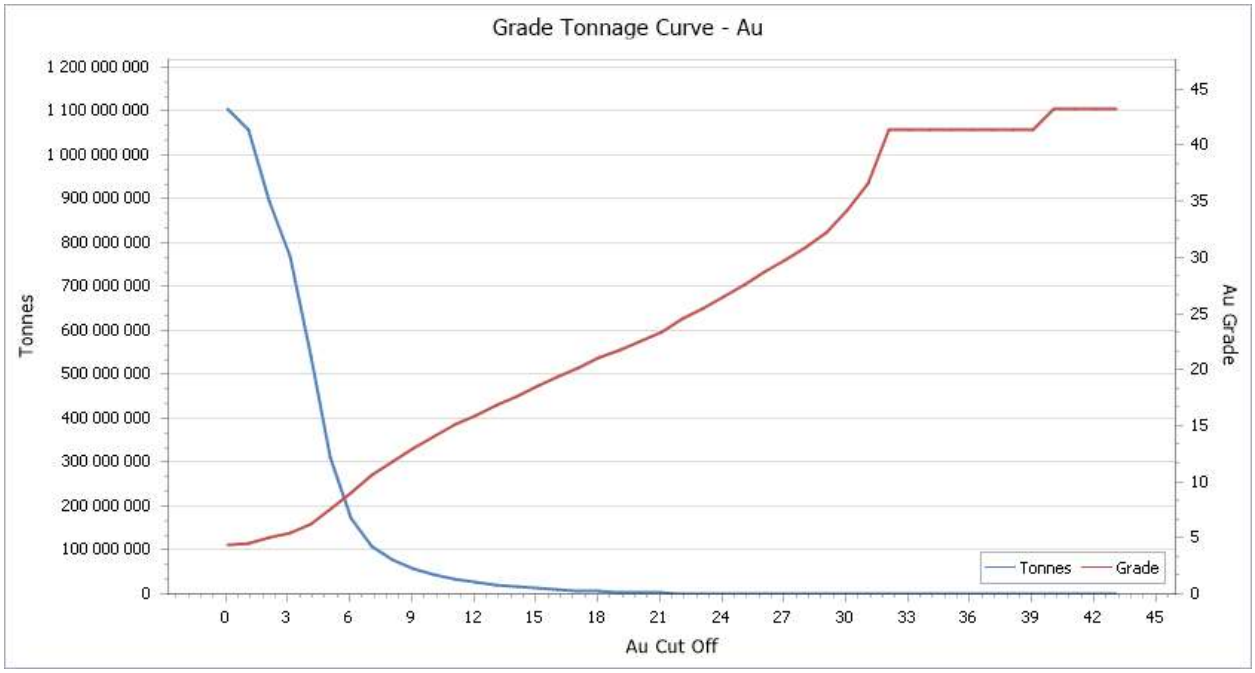

Figure 3-7: Grade Tonnage Curve

A grade tonnage curve graphically depicts the ore (in tonnes) available above a particular mineral grade (cut-off grade). The figure evinces a sharp decline in the available tonnes as the cut-off

grade increases. At a cut-off grade of 0% there is 1 085 Mt, which is the total in situ ore. At a cut-off grade of approximately 18% the available ore has practically declined to zero. Due to the sharp decline, all ore in the mineable limits will be scheduled, in order to obtain maximum extraction. A histogram of the gold frequencies is delineated in Figure 3-8.

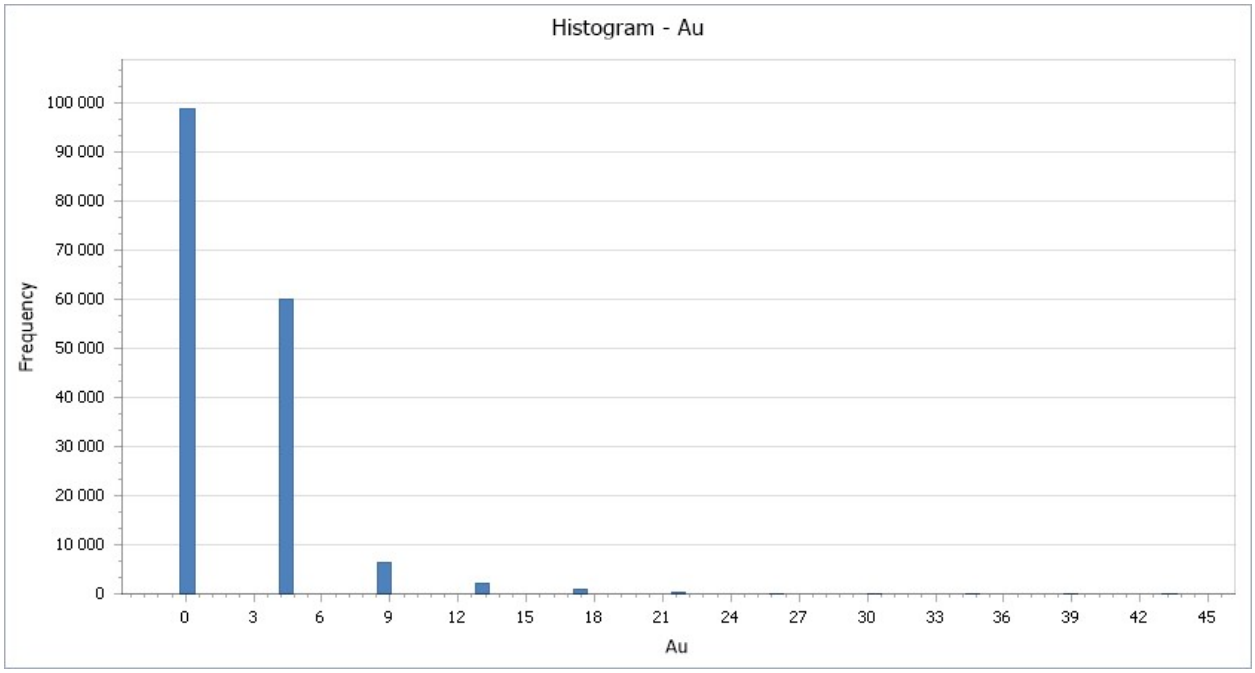

Figure 3-8: Gold Frequency Histogram

The frequency histogram denotes the amount of blocks (168 811 blocks, as per the geological model) that have gold grades (measured in g/t) in the ranges demarcated on the x-axis. This illustrates that the range identified in Table 3-1 is not a concern and is resultant from a couple of outliers. The predominance of the ore is contained within the ranges below 9 g/t.

In order to determine the mineable ore, the village, conservation area and stand-off zones are required to be excluded. This reduces the orebody to 845 Mt, with 114 Moz of gold, as mineable in situ ore. That is a reduction of 22% in ore and 25% in gold content. This will be utilised in the succeeding division, where the mining method and mine plan are discussed.

3.2.3 Mining method and mine plan

Open pit mining will be utilised for the extraction of the gold orebody. Open pit mining is a surface mining method, wherein the waste is removed to access and mine the ore. The primary reason for this mining method is the shallow, tabular/flat nature of the orebody and absence of any faults and dykes (geological intrusions). The waste is assumed to be competent, hard material and will

be blasted. The assumptions for the mine plan are explicated in Table 3-3. The detailed mine plan is as per the Annexure.

Table 3-3: Mine Plan Assumptions

DESCRIPTION	VALUE	COMMENT
Angle of Repose	80º	For waste and ore
Box Cut	-	Originate in southern tip
Production Tempo	300 000 t/d	Applied constant through the year – in waste and ore
Ramp-Up Duration	4 yr	Year 1: 50%; year 2: 80%; year 3: 95%; year 4: 100%
Plant Capacity	-	Enough to process ore feed

The angle of repose is the incline at which the material will be stable and not cause a collapse/landslide. As an example, loose sand has an angle of repose of 32º, which increases as the hardness and competency of the material intensifies. For this case study competent material is assumed for both waste and ore, hence an 80º angle of repose.

The box cut refers to the mining origin point. This area is prepared before mining commences, for this study the cost will be included in the general capital. The time required is deemed negligible. For scheduling purposes, the mining area has been divided into 100 m x 200 m mining blocks. This is to allow for structured extraction. Mining takes place on a cookie cut principle. This means that only the edges, along the mining boundary are cut according to the angle of repose (at 80º), to allow for design losses. The rest of the mining area is cut straight down and no allowance is made for benches (vertical steps).

A constant production tempo of 300 kt per day is applied throughout the LOM. The only period wherein the production tempo is applied differently, is during the four year ramp-up period. The ramp-up period allows the project to realistically start the operation and increase pace to the desired production tempo.

The plant capacity refers to the amount of ore that the processing plant can manage. This volume frequently determines the desired production tempo. The plant is commonly the most expensive component in the mining process. It is logical to make the most expensive component the bottleneck, to ensure optimal use. However, due to the setup of this study, this is not possible. It

is assumed, for the case study, that the plant can process all material provided, i.e. an over-designed plant.

As a result of the tabular orebody, strip mining will be utilised. In strip mining, the strips and blocks follow the 100 m x 200 m blocks previously described. The strips and blocks are illustrated in Figure 3-9.

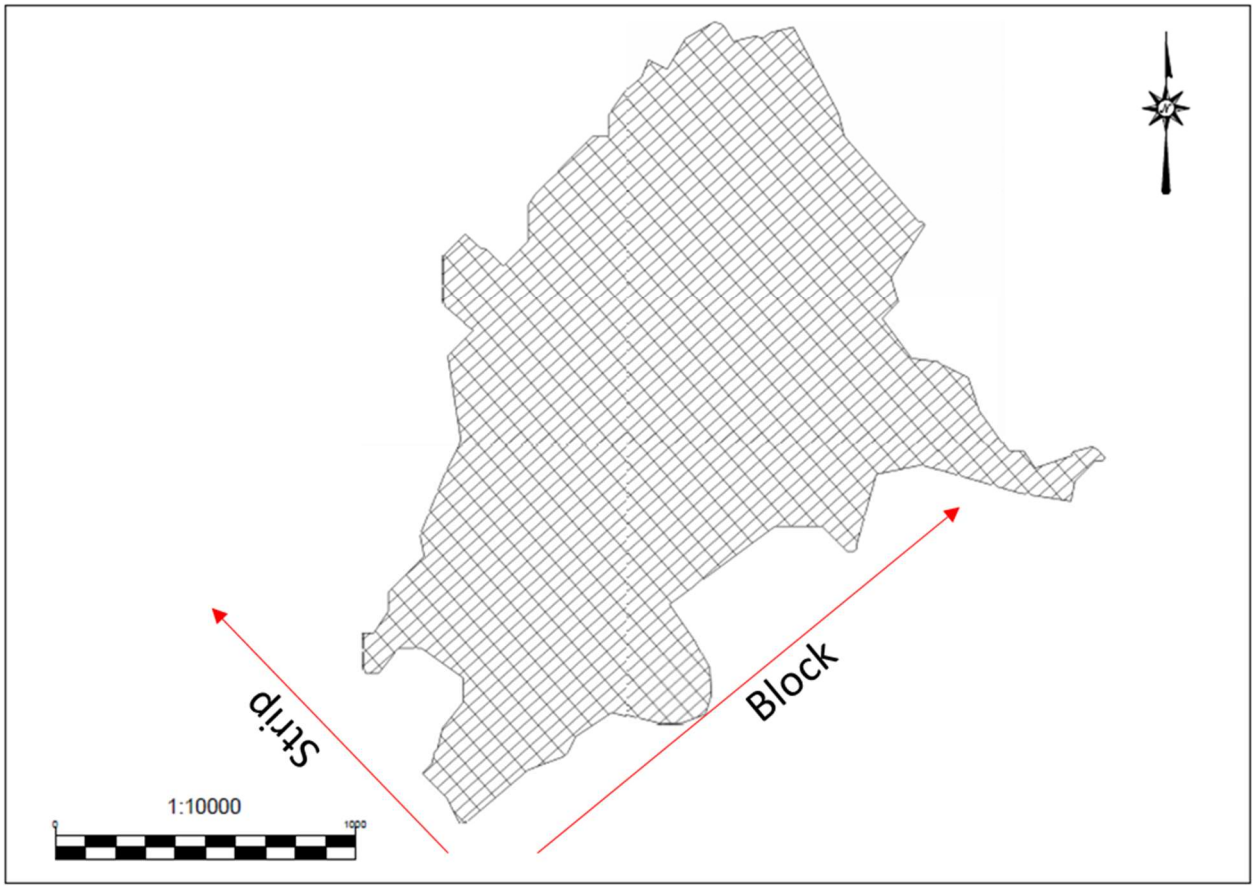

Figure 3-9: Mining Layout

The strips and blocks are applied to guide the mining sequence and prevent the schedule from mining selectively (i.e. jumping around). Deswik.Scheduler is utilised to organise the blocks in a logical sequence, with the resultant mine plan (period progress plot) graphically depicted in Figure 3-10.

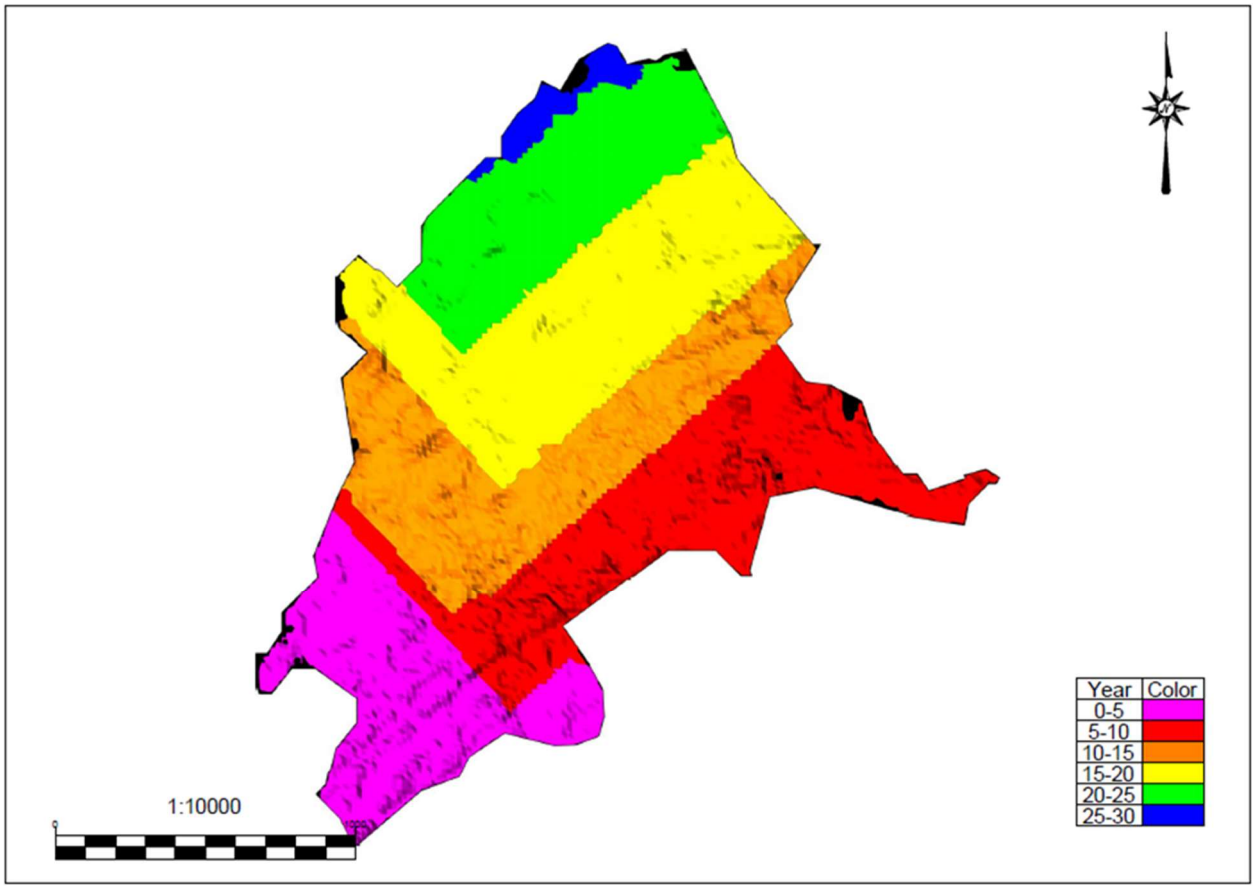

Figure 3-10: Period Progress Plot

The plot is delineated in five year intervals. Mining commences in the southern tip (box cut location) and progresses toward the northern tip (where waste is the thickest). Mining concludes in year 26 (blue area). The mine plan (built in Deswik.Scheduler and refined in MS Excel) is summarised in Table 3-4. The mine plan commences with the resource (geological model) and progresses to a reserve. The table has been designed in a manner ensuring that it is auditable, as discussed per Diering *et al.* (2012) in Chapter 2. The process to determine the reserve has three distinct groupings, which are expressed below.

- In situ to Run of Mine (ROM), refers to ‘mine design and scheduling’;
- ROM to plant product , the ‘processing’ component; and
- ‘Economic’, the third component, which will be applied in the financial model.

Table 3-4: Mine Plan Output Summary and Reserve Calculations

RESOURCE –TO– RESERVE	DESCRIPTION	UNIT	FACTOR	MATERIAL (T)	CONTENT (T)	CONTENT (MOZ)	GRADE (G/T)
Resource	In situ:			1 085 300 294	**4 732**	**153**	4.36
	Mineable Restrictions	%	**22**	**240 178 409**	**1 176**	**38**	
	Mineable In-Situ:			**845 121 885**	**3 556**	**115**	4.21
	Economic Cut-Off	%	Not Considered				
	Physical Cut-Off	%	**8**	**70 077 150**	**409**	**13**	
	Mineable Ore:			**775 044 735**	**3 147**	**102**	4.06
	Mining Losses	%	10	**77 504 474**	**315**	**10**	
	Dilution	%	5	**38 752 237**			
	Run of Mine (ROM):			**736 292 498**	**2 832**	**91**	**3.85**
	Oversize	%	5	**36 814 625**	**142**	**5**	
Reserve	Plant feed:			**699 477 873**	**2 691**	**87**	**3.85**
	Plant Yield Losses	%	15		**404**	**13**	
	Plant Product				**2 287**	**74**	**3.27**

Waste	Mineable Waste		**1 990 592 154**
	Stripping Ratio	Waste:Ore	**2.57**
	Total Mineable Material		**2 765 636 889**

Legend

xxx	Input
xxx	Calculated
xxx	Linked Cell
xxx	Output

The table is formulated with the following columns:

- Resource-to-Reserve: To illustrate where in the process the resource and reserve are calculated. This column also includes the heading for the section where waste is calculated;
- Description: Descriptive heading for each row to indicate the progression from resource to reserve;
- Unit: The unit of measurement for the value (see next point) that is applied to each row. (The last four columns are as per the unit noted in the headings);
- Factor: The value applied to each row;
- Material (t): The amount of ore/waste calculated by applying the factors, measured in tonnes;
- Content (t): Amount of gold in the ore, measured in tonnes and calculated by multiplying material with the grade;
- Content (Moz): Amount of gold in the ore, measured in million ounces and converted using a ratio of 31.1 g/oz; and
- Grade (g/t): The amount of gold in the ore, as grams of gold per tonne of ore material.

The results in the table have been colour coded to indicate the process used. The legend is shown at the bottom of the table and has the ensuing four categories:

- Input: Assumed integers to enable necessary calculations, in the table the mining modifying factors for this study (i.e. mining losses, dilution, oversize loss and plant yield loss) have been included as input values;
- Calculated: These values are calculated using either the values in the table or the mine plan output from Deswik.Scheduler;
- Linked cell: These cells are linked to cells from the Deswik.Scheduler output; and
- Output: This is the resultant value for this table, it shows the reserve and total mineable material (mineable ore plus waste).

The in situ ore and the mineable in situ are the same as delineated in Table 3-2. This shows that 22% of the ore is removed as a result of the mineable restrictions (conservation area, etc.). The gold content grade alters from 4.36 g/t to 4.21 g/t; as a result the content reduces by 25%. This implies that the areas that were excluded have high grade ore.

This study does not investigate an economic cut-off grade. As previously discussed, the grade tonnage curve in Figure 3-7 illustrates that the ore rapidly declines with an increase in the economic cut-off grade. The physical cut-off is as a result of the 80º angle of repose (see Table 3-3) applied to the mining area perimeter. The resultant mineable ore is 775 Mt with a grade of 4.06 g/t. The ore is 8% lower than the mineable in situ. The decrease in grade is again notable, suggesting that the perimeter area has high-grade ore.

Deswik.CAD is used to modify the orebody up to the mineable ore. Within this process the physical shape and size are manipulated. Each step changes the material and content fields, with different percentage values. An example of this is the 22% the ore decreases, along with the 25% reduction in the content, during the conversion from in situ resource to mineable in situ. All the material contained in the mineable ore will be extracted. The mining modifying factors that will be studied in further detail are applied to the mineable ore and are required to be readily editable. For this reason, these modifying factors are applied using a mathematical approach in MS Excel. All the applied modifying factor input values, are commonly used rounded values typically found in a mining study.

For this study, the production tempo has been applied to the mineable material (includes waste). In practice, the production tempo is characteristically applied to the ROM material. ROM material refers to the mineable ore and waste that will be extracted from the pit, e.g. by means of truck and shovel. In this instance, all factors will be applied in Deswik.Scheduler. The case study has been formulated in this manner to facilitate a schedule output from Deswik.Scheduler, prior to performing calculations in MS Excel. The MS Excel calculations are necessary for sensitivity analysis purposes. See the full mine plan (schedule) in the Annexure.

Mining losses of 10% and dilution of 5% have been applied to the mineable ore. Mining losses signify losses that occur as a result of inefficient mining practices, this constitutes ore that is not mined. There is ordinarily not a clear, visible distinction between ore and waste, consequently some ore is discarded as waste, or simply not extracted. Mining losses directly impact both ore and gold content, causing a decline in these values. Dilution is also as a result of inefficiencies, occurring at the interface between waste and ore. Some waste is mined as ore and vice versa. The dilution is only applied to the ore, not the content. This results in an increase in the amount of ore. The content does not increase, because there is no gold in the waste. Subsequent to the application of these factors, the resultant grade of the ore is recalculated and shows a decrease from 4.06 g/t to 3.85 g/t. The ROM ore is calculated as 736 Mt.

The ROM ore is transported to the plant and oversize material is removed before processing. The oversize material is removed with a mesh grid (grizzly). This eliminates rocks too large for the plant, as well as some foreign debris (for instance, branches) that has mixed in with the ore. The

oversize material also contains gold, thus reduces both the ore and content. Once the oversize has been removed, the plant feed remains, comprising the ore that will be processed. The plant feed is 699 Mt with an unchanged grade of 3.85 g/t.

The processing phase incurs some losses (plant yield losses) and it has been assumed that 85% of the gold content will be recovered. The plant yield losses account for inefficient processing practices, for example fine gold incorrectly discarded from the plant, as waste. From a deposit that originally contained 153 Moz of gold (in situ), it is anticipated that 74 Moz can be successfully extracted and sold on the market.

The entire process has taken the gold deposit from a resource with 1 085 Mt of ore, to a reserve with 699 Mt. That is a decrease in ore of 36%, and a reduction of 52% in the gold content.

The factors identified as modifying factors in this section, incorporate mining losses; dilution; oversize; and plant yield losses. These modifying factors will be evaluated later in the study. The subsequent section will integrate the mine plan into a financial model.

3.3 Financial model

The most basic calculation for profit is:

$$Profit = Revenue - Cost$$

This formula can be refined to include all revenues and all costs. Table 3-5 lists the financial model assumptions and inputs. For ease of calculation the model has been created utilising US dollars, which alleviates most of the issues identified by Rendu (2002), for instance exchange rate complications.

Table 3-5: Financial Model Cost Inputs

DESCRIPTION	UNIT	VALUE
Commodity price	$/oz	1 200
Capex	$	1 500 000 000
Mining:		
Fixed	$/yr	50 000 000
Variable	$/t	20
Processing:		
Fixed	$/yr	30 000 000
Variable	$/t	20
Royalties	% of revenue	5
Depreciation	%	N/A (Contractor)
Tax	%	35
Change in working capital		0
Discount factor	%	10

The table has three columns:

- Description: Descriptive heading for the row;
- Unit: The unit of measure for the value; and
- Value: The numeric value of the assumption or input.

Gold price varies over time, but the study is based on a constant gold price of 1 200 $/oz. Capex is assumed at $1.5 billion. The project is considered a green fields project (no mining has taken place yet), which requires all infrastructure, including a processing plant, roads, offices, etc.

Mining has a fixed annual cost of $50 million. This is to pay salaries; wages; long term contracts; etc. The variable cost per tonne is $20 per tonne and is demarcated for, *inter alia*, fuel; tyres; and maintenance. Processing has a fixed yearly cost of $30 million. This is for the same cost components as the mining fixed cost. The variable processing cost is $20 per tonne and accounts for maintenance; chemicals; etc. It is noteworthy that mining costs exclude all processing plant and related costs.

Royalties are set at 5% of the revenue. Royalties are required as payment to the community where mining takes place, in order to give back and uplift the community. For this study no depreciation has been considered, as a mining contractor is preferred, rather than owning and operating equipment. Tax has been set at 35% for the venture; this is a generally accepted value. Change in working capital is not considered for the purposes of this study. A general discount factor of 10% has been adopted. When these factors are applied to the mine plan the costs are as per Table 3-6. See the Annexure for detailed calculations.

Table 3-6: Cost Components

DESCRIPTION	UNIT	LOM TOTAL	YEARLY AVERAGE
Revenue	$M	88 239	3 394
Capital	$M	1 500	-
Total Operating Cash Cost - excl. Royalties	$M	78 736	3 028
Mining:	$M	56 613	2 177
Fixed	$M	1 300	50
Variable	$M	55 313	2 127
Processing:	$M	14 770	568
Fixed	$M	780	30
Variable	$M	13 990	538
Logistics	$M	7 353	283

The table has four columns:

- Description: Descriptive heading for the row;
- Unit: The unit of measure for the value, i.e. million dollars;
- LOM total: summative value over LOM; and
- Yearly average: LOM total divided by LOM (26 years for this study).

The calculated values do not incorporate discounting which will be attended to further in the discourse. A revenue of $88.2 billion is achieved, through the application of the cost components

(utilising the values from Table 3-4 and Table 3-5). Allocated yearly, the average revenue is $3.4 billion per annum. Prior to the commencement of mining, a capital outlay of $1.5 billion is required. The initial capital expenditure is to ensure all requisite infrastructure is available, inclusive of roads, offices, basic facilities and a processing plant. The primary capital is not converted into an annual average, as it is considered a once-off outlay, necessary to provide all substructure and foundation requisites, which will facilitate the commencement and functioning of the venture. For simplicity, the entire capital sum will be applied in year one. The total operating cash cost (excluding royalties) is calculated from the three categories sited below it, viz. mining; processing; and logistics. The formula to calculate this is:

$$Total\ operating\ cash\ cost\ (excl. royalties) = Mining\ costs + Processing\ costs + Logistics\ costs$$

Mining costs have been apportioned into two distinct groups, comprising fixed and variable expenditures, as previously explicated. The fixed expenses are applied every year, amounting to an average of $50 million per annum, with an aggregate of $1.3 billion over the LOM. The variable mining cost is equivalent to an annual average of $2.1 billion, accruing to $55.3 billion for the LOM. This resultant, total accumulated cost of mining is $56.6 billion, with a cumulative average of $2.2 billion per annum. The processing costs are calculated by the same principle, with an annual accrual of $0.6 billion and a summative LOM expenditure of $14.8 billion. The final expense component comprises the logistics costs, which amount to $0.3 billion per annum, with an amassed aggregate of $7.4 billion incurred over the LOM. Consequently, coalescing these expense elements, results in an overall, total operating cash cost (excluding royalties) of $3.0 billion annual average, which is accrued to $78.7 billion over the LOM. Despite the overall expenditure, the revenue still exceeds the expenses, which connotes a potentially profitable operation. Table 3-7 expounds the operating costs.

Table 3-7: Operating Costs

DESCRIPTION	UNIT	LOM TOTAL	YEARLY AVERAGE
Total Operating Cash Costs - excl. royalties:	$M	78 736	3 028
Total Operating Cash Costs per oz sold	$/oz	1 071	1 225
Total Operating Cash Costs per tonne mined	$/t	28.47	28.44
Royalties	$M	4 412	170
Total Operating Cash Costs:	$M	83 147	3 198
Total Operating Cash Costs per oz sold	$/oz	1 131	1 285
Total Operating Cash Costs per tonne mined	$/t	30.06	30.02

The columns are consistent with Table 3-6. The operating cash cost (excluding royalties) is either divided by the gold product ounces or total material mined (values are in accordance with Table 3-4) to determine the true cost of mining. These values assist in benchmarking comparably with other operations in the region or within the same commodity. For this venture, the total operating cash costs (excluding royalties) of $78 billion, can be dispersed and assayed as denoted below.

- Per ounce of gold sold – $1 071 per ounce: This provides a greater comprehension of what the expenditure is for every ounce of gold sold on the market; and
- Per tonne mined – $28.4 per tonne: The total material mined includes development and waste, clarifying the expense required for every tonne mined, which enables ascertaining the cost of mining waste.

The yearly averages are calculated, but will not be deliberated, as they are not correctly weighted.

The total operating cash cost is calculated using the ensuing formula:

$$Total\ operating\ cash\ cost = Total\ operating\ cash\ cost\ (excl\ royalties) + Royalties$$

The royalties can be calculated from the revenue of the operation and are applied irrespective of profitability. The annual royalties average $170 million, with an aggregate of $4.4 billion for the LOM. To provide a comprehensive conception of the entire expenditure, the total operating cost is recalculated to include the royalties, utilising the identical process demarcated previously. This renders an average, total expense of $3.2 billion per annum, accruing to a LOM cost of $83.1

billion. When apportioned, the modification in the cost amounts to $1 131 per ounce of gold sold and $30 per tonne of mined material. The revenue remains greater than the recalculated total operating cost, thus continues to indicate a potentially profitable mining operation. The subsequent step entails computing the NPV, the calculations for which are portrayed in Table 3-8 (with the equivalent column structure as the previous two tables).

Table 3-8: NPV Calculation

DESCRIPTION	UNIT	LOM TOTAL	YEARLY AVERAGE
Revenue	$M	88 239	3 394
Total Operating Cash Costs	$M	83 147	3 198
EBITDA:	$M	5 091	196
Margin (% of Revenue)	%	6	
Depreciation - N/A (Contractor)	%	-	-
EBIT:	$M	5 091	196
Margin (% of Revenue)	%	6	
Tax	$M	4 414	276
Depreciation		-	-
Change in Working Capital		-	-
Capex	$M	1 500	
Free Cash Flow	$M	-822	-32
Discount Factor	%	10	
Discounted Cash Flow			29
NPV	$M	**757**	

The initial stages of the calculations entail the application of the succeeding formulae:

$$EBITDA = Revenue - Total\ operating\ cash\ costs$$

$$EBIT = EBITDA - Depreciation - Amortisation$$

$$EBIT\ (margin\ \%\ of\ revenue) = EBIT \div Revenue$$

The revenue and total operating cash costs are delineated in order to calculate the earnings before interest; tax; depreciation; and amortisation (EBITDA). The EBITDA averages $196 million annually and accumulates to $5.1 billion over the LOM. As a contractor is retained the earnings before interest and tax (EBIT) remain unaltered. Expressed as a percentage of the total revenue the EBIT constitutes 6%, which can be utilised as a comparison factor when evaluating the venture against other mining operations.

The Free Cash Flow (FCF) is ascertained through applying the ensuing formula:

$$FCF = EBIT - Tax + Depreciation - Change\ in\ working\ capital - Capex$$

Taxes are only applied to positive yearly EBIT values, equating to an annual average taxation of $276 million (in years with a positive EBIT), or a total of $4.4 billion over the LOM. The Annexure contains comprehensive calculations. As previously stated, depreciation and working capital are not considered within the scope of this study. A Capex of $1.5 billion is applied, this occasioning an FCF for the project of -$822 million (a yearly average of -$32 million). A negative value is not preferred, but does not necessarily indicate a negative NPV. An investigation of the yearly data evinces a negative FCF for the initial years, which transforms to a positive FCF for the majority of the LOM, but returns to a negative towards the end of LOM. An in-depth evaluation would possibly re-evaluate the mine plan, advocating ceasing operations and abandoning mining in the final years, when the FCF is negative, in accordance with the work of Evatt *et al*. (2012).

For this study, the ultimate phase involves determining the DCF. A general value of 10% is exercised to discount the FCF. Through the application of the discount factor the yearly average DCF is modified and becomes positive, with a value of $29 million. A summation of the DCF yields the project NPV. The final NPV for the mining project is $757 million. The yearly NPV (cumulative DCF) is portrayed in Figure 3-11.

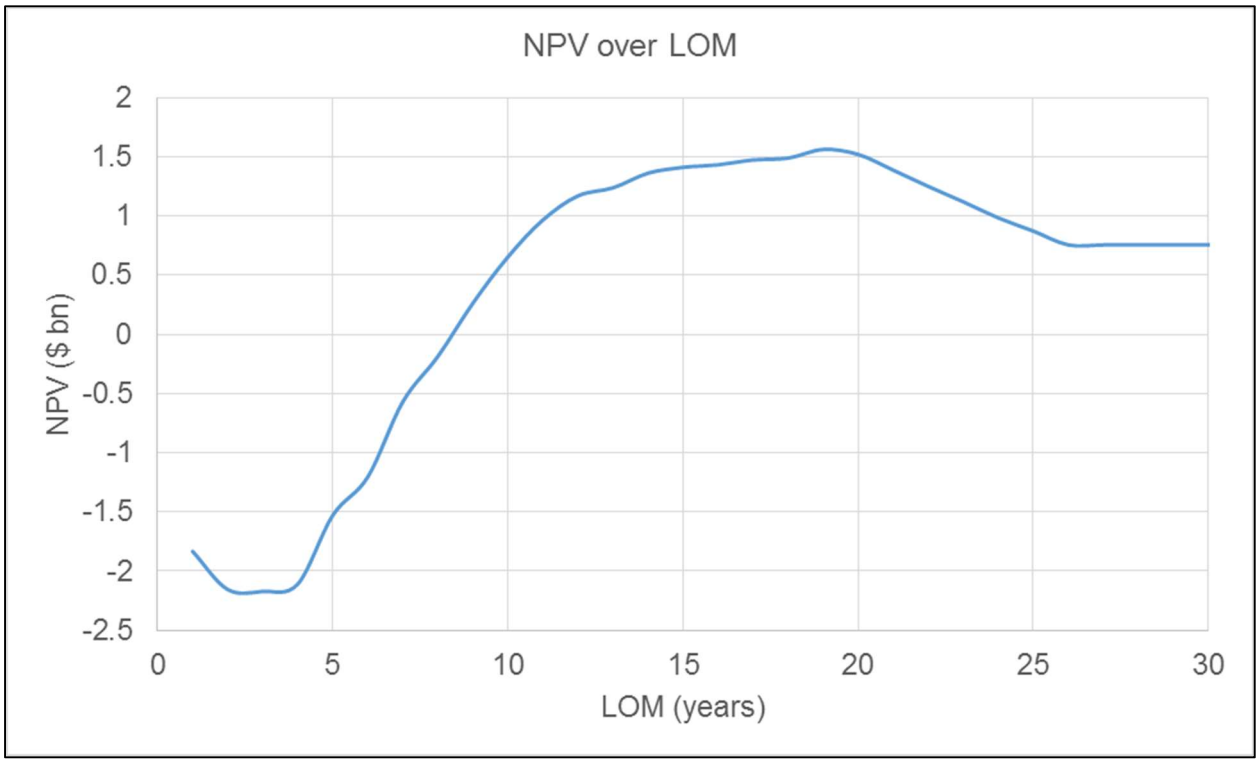

Figure 3-11: Project NPV (Cumulative DCF) Measured over LOM

It can be seen that the NPV is initially negative, increasing in magnitude in the initial years, prior to the commencement of positive cash flow. The project displays positive cash flow from year four, repaying the debt in year nine. The period between years nine and nineteen is where the venture renders a profit. Post-year nineteen the cash flow begins to decline. This could imply that the mine might opt to cease operations around year twenty, abandoning the unprofitable portion of the mine (at a maximum NPV of $1.5 billion). In this instance, the work conducted by Evatt *et al*. (2012), regarding economic uncertainty and extraction, can be applied.

Within the projects milieu, NPV is frequently perceived to constitute the deciding factor; with projects displaying a positive NPV subject to greater investigation for eventual economic extraction, while negative NPV ventures are parked, scrapped or sold. From the analysis this project has promising prospects for further exploration, with the intention of eventual execution.

The subsequent section explores variations and fluctuations in the modifying factors, through the application of sensitivity analysis. In addition to the mining modifying factors identified earlier, a few economic modifying factors will also be investigated, viz. variable mining cost; variable processing cost; royalties; and discount factor.

3.4 Sensitivity analysis

Sensitivity analysis is deemed the preferred method by which to examine the impact of variations in a modifying factor on the NPV of the case study. The itemised lists below comprise the central modifying factors identified, throughout the case study, to assess and analyse.

Mining Modifying Factors:

- Mining Losses;
- Dilution;
- Oversize; and
- Plant Yield Losses.

Financial Model Modifying Factors:

- Variable Mining Cost;
- Variable Processing Cost;
- Royalties; and
- Discount Factor.

3.4.1 Mining modifying factors

The mining modifying factors will be evaluated in the sequence outlined above. The initial order is equivalent to that by which the factors are applied during resource-to-reserve calculations. After evaluation the factors with the greatest impact will be highlighted as controlling parameters. The first modifying factor is mining losses, with the impact thereof displayed graphically in Figure 3-12.

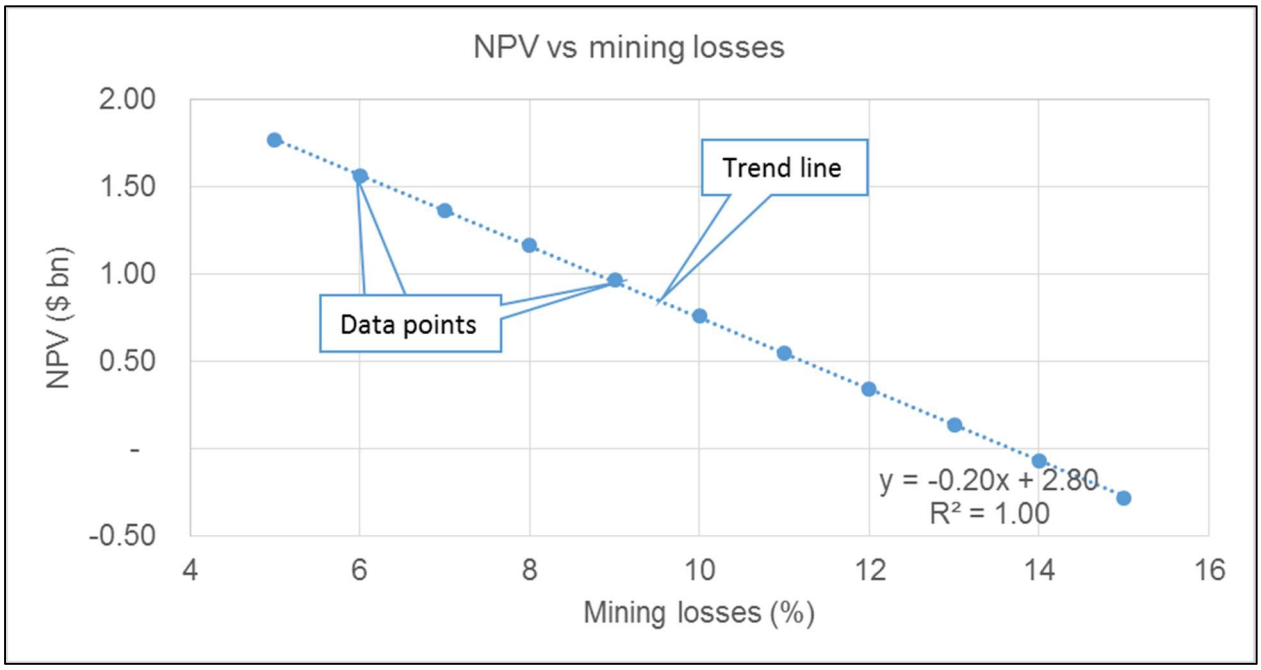

Figure 3-12: NPV Variation with Changes in Mining Losses

The figure illustrates that as the mining losses increase, the NPV decreases and vice versa; connoting that mining losses has a negative, linear correlation with the NPV. Consequentially, the NPV will change in the opposite direction of an alteration in mining losses. A linear trend line (MS Excel function that measures data correlation) has been added and has an R^2-value of one. This indicates that the trend line correlates perfectly with the data points of mining loss to NPV. The trend line function produces a linear equation, by which the data can be interpreted. The formula for a straight line is:

$$y = mx + c$$

The y-value denotes the NPV, while the x-value comprises the mining loss (the x-value will change for each new modifying factor). The m-value is the gradient, indicating the relationship between the x- and y-values. The c-value designates the y-axis intersection, when the x-value is zero.

The c-value for the equation is 2.8, thus the NPV is \$2.76 billion if no mining losses are considered. The m-value is -0.2, this denotes the negative correlation. For each increase of a percentage point in mining losses, the NPV decreases by \$200 million. The inverse is also applicable; a percentage point decrease in the mining losses renders a \$200 million increase in NPV. A mining loss of 13.65% results in a zero NPV. Thus, if all other factors were kept constant

and a mining loss exceeding 13.65% was applied, the mining project would have a negative NPV. The succeeding modifying factor explicated is dilution, displayed in Figure 3-13.

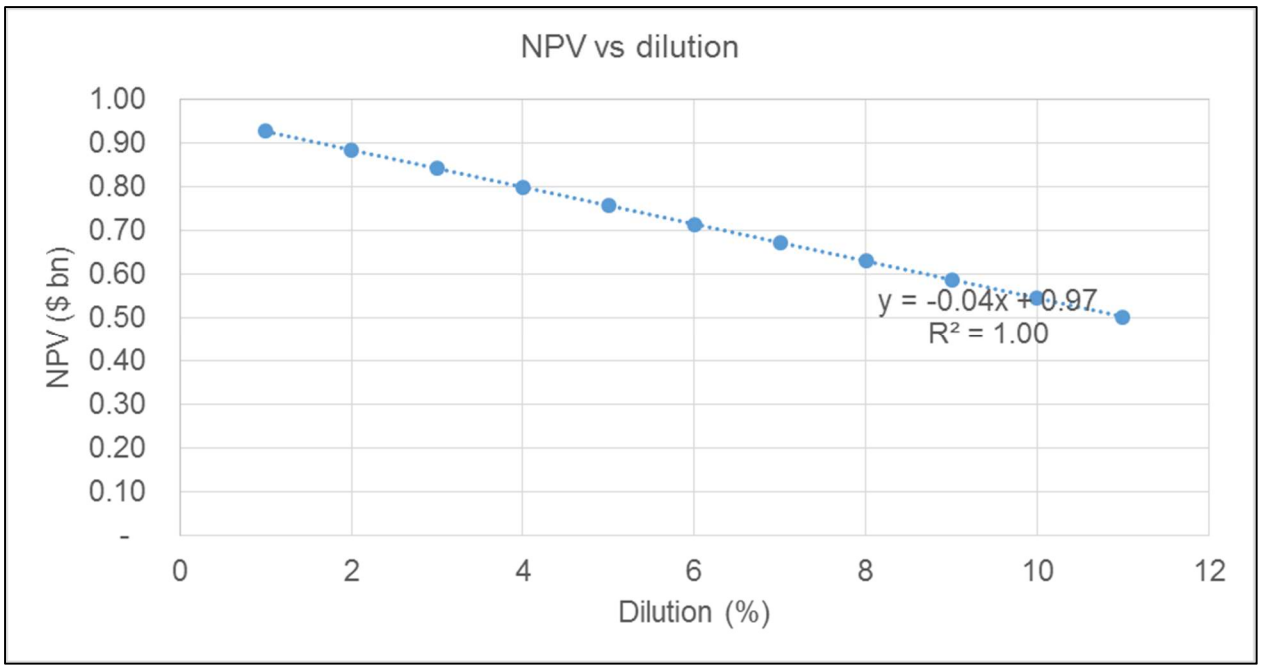

Figure 3-13: NPV Variation with Changes in Dilution

Similarly, dilution has a negative, linear correlation with NPV. The R^2-value is one, indicating a perfect correlation between the trend line and data set. If no dilution was taken into account the NPV would be $ 0.97 billion. The m-value is negative (-0.04), signifying that the NPV will change by $42 million for each percentage point alteration (converse direction) in dilution. The oversize is subsequent, illustrated in Figure 3-14.

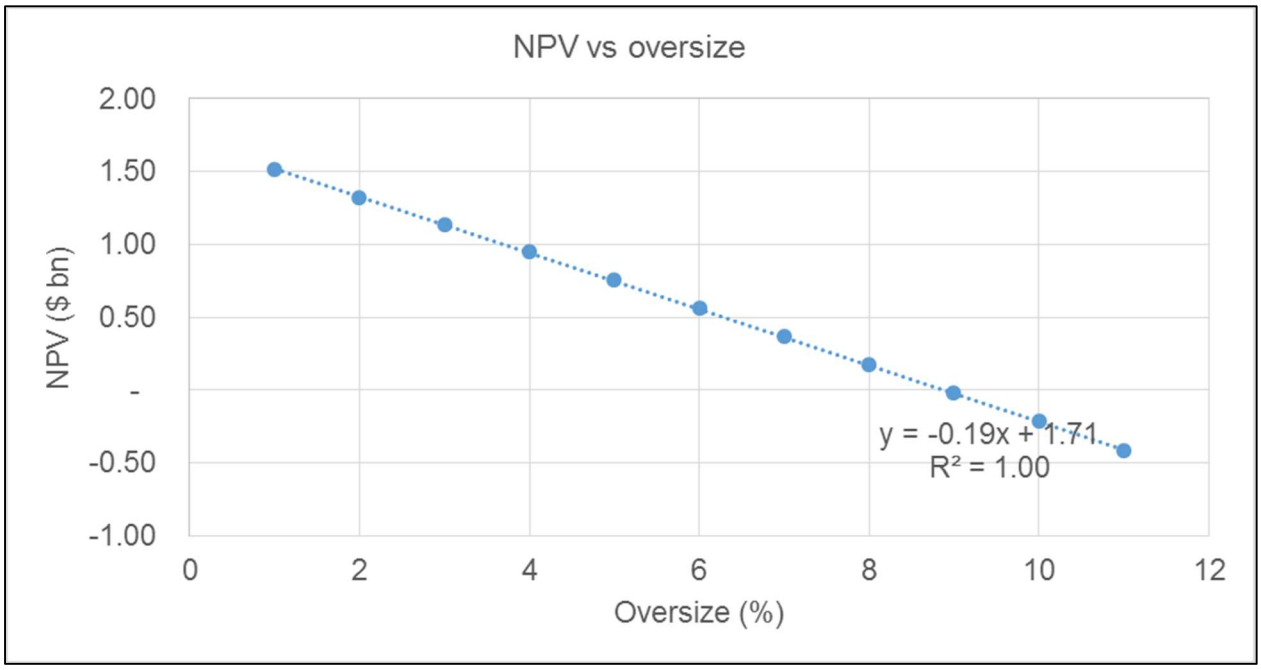

Figure 3-14: NPV Variation with Changes in Oversize

Analogously, with the prior two facets, oversize data has a perfect correlation with the trend line ($R^2 = 1$), confirming a negative, linear correlation between oversize and the NPV. If there is no oversize, the NPV is $1.70 billion. Each percentage point increase in oversize causes the NPV to decrease (m-value is negative) by $193 million, with the reverse also valid. The final mining modifying factor constitutes plant yield loss, displayed in Figure 3-15.

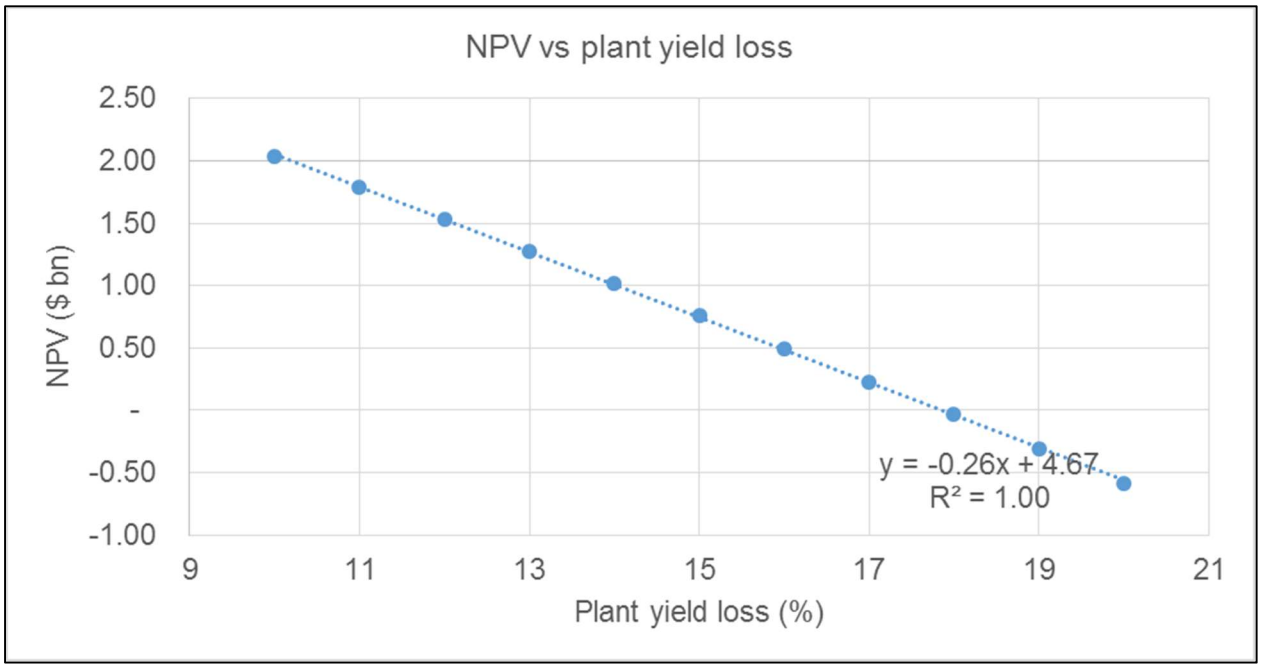

Figure 3-15: NPV Variation with Changes in Plant Yield Losses

Plant yield loss has the strongest impact on NPV. There is a negative, linear correlation, with an R^2-value of one. Each percentage point alteration in the plant yield loss engenders an opposite change in the NPV of about $263 million, a negative m-value of -0.26. If no plant yield loss was considered the NPV would be $4.58 billion.

An analysis, of the four mining modifying factors explicated, evinces that the NPV can be significantly impacted by alterations in these factors. All the factors have a negative, linear correlation with the NPV. The mining modifying factors are summarised, in order of greatest impact on NPV, in Table 3-9.

Table 3-9: Mining Modifying Factors

DESCRIPTION	Model VALUE	m-VALUE	NPV IF ZERO ($ bn)	NPV ZERO INTERSECTION (%)
Plant Yield Loss	15	-0.26	4.58	17.83
Mining Loss	10	-0.20	2.76	13.65
Oversize	5	-0.19	1.70	8.90
Dilution	5	-0.04	0.97	22.81

The table has the following columns:

- Description: Descriptive heading for the row.
- Model Value: The value applied for the initial NPV calculations within the case study;
- m-Value: The correlation between NPV and the modifying factor discussed, consistent with the linear equation;
- NPV if Zero ($ bn): Denotes the NPV achieved if the modifying factor under assessment is considered zero; and
- NPV Zero Intersection (%): The x-values at which the NPV is zero, constituting the critical value; whereby, if it is exceeded, the NPV would be negative and the project would no longer be deemed viable.

The m-value and NPV show a distinct correlation. A higher m-value indicates a greater impact on the NPV with alterations in the modifying factor. The final column allows for a clear understanding of the difference between the model value and the value at which the NPV would be zero.

From the preceding assessment, the controlling parameters (per Rendu, 2002) have been established as plant yield loss; mining loss; and oversize. These all impact the NPV considerably when altered. Furthermore, it is deemed important to note that the model value and the value at which the NPV is zero, do not differ significantly. Dilution is not identified as a controlling parameter, as it has very little impact on the NPV. The subsequent section expounds the economic modifying factors identified during the setup of the financial model.

3.4.2 Economic modifying factors

This division will succinctly investigate the impact of a few selected economic modifying factors, viz. variable mining cost; variable processing cost; royalties; and discount factor. This is to ascertain whether they also substantially impact the NPV. The variable cost for both mining (Figure 3-16) and processing (Figure 3-17) are not expressed in percentages, but in dollar per tonne values. These factors are significant, as mining will not occur in their absence.

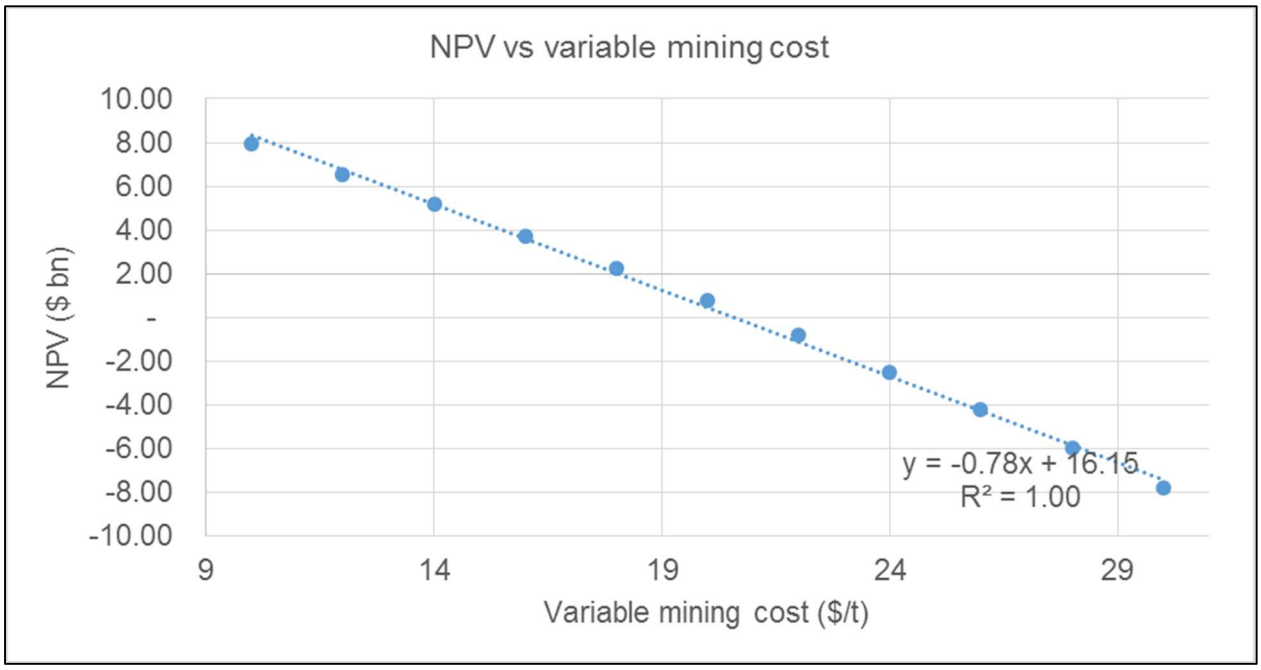

Figure 3-16: NPV Variation with Changes in Variable Mining Cost

From the figure it can be visually observed that there is not a perfect correlation between the data and the trend line. However, the R^2-value is one, which signifies a negative, linear correlation. The variable mining cost has a significant impact on the NPV, the greatest influence of all the modifying factors discussed. The NPV would be $14.60 billion if the variable mining cost was zero. With each dollar that the variable mining cost increases, the NPV decreases by approximately $780 million. Conversely, the NPV will increase by approximately $780 million for each dollar that variable mining cost decreases. Variable processing cost is reviewed next (Figure 3-17).

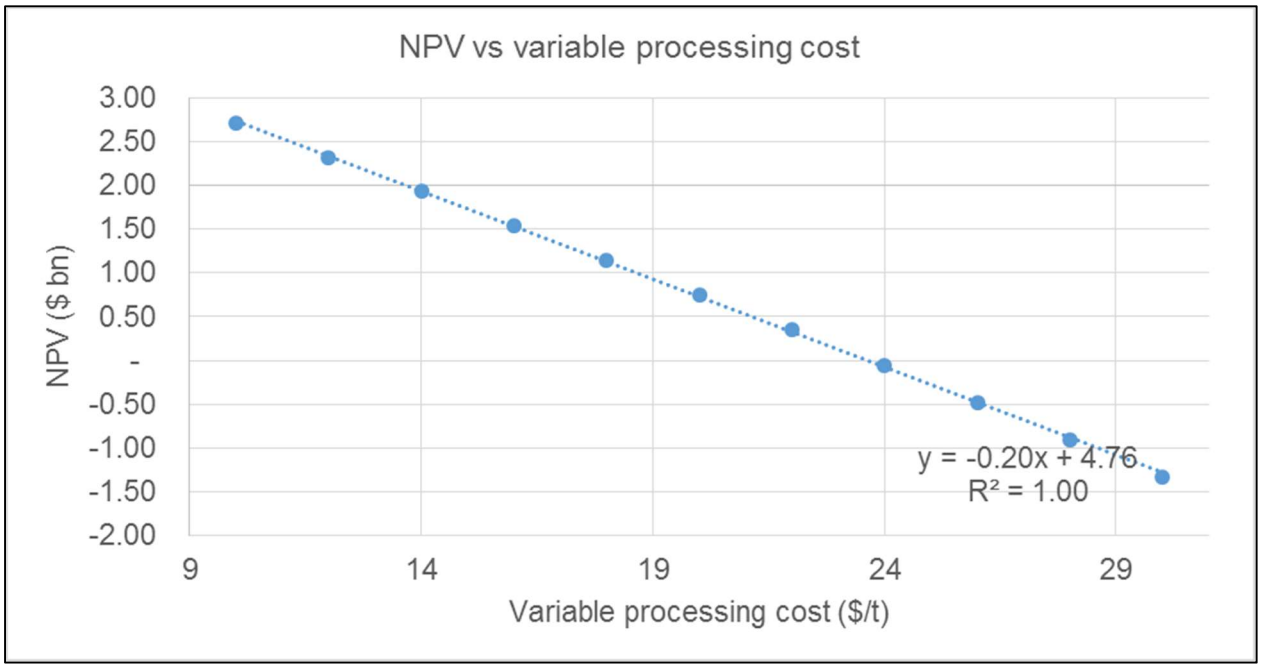

Figure 3-17: NPV Variation with Changes in Variable Processing Cost

The variable processing cost has far less of an impact on the NPV and causes a decrease of $200 million with every dollar value increase and vice versa. The NPV would be $4.65 billion if no variable mining cost was applied. Figure 3-18 illustrates the impact of royalties.

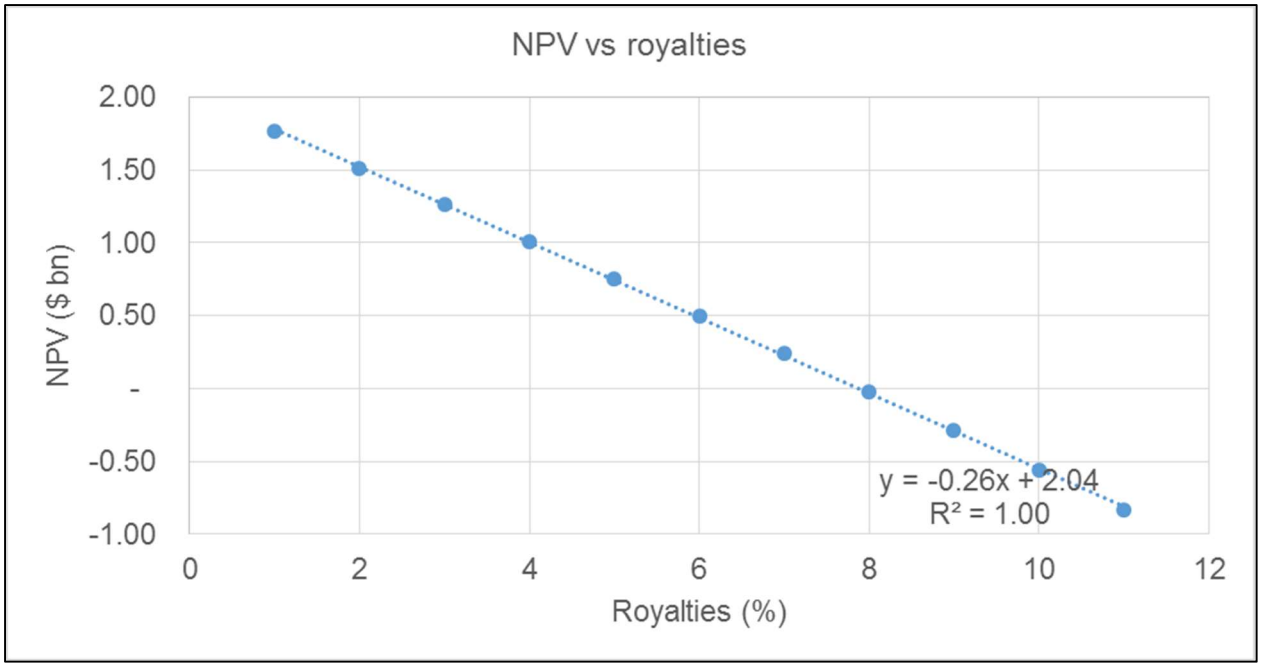

Figure 3-18: NPV Variation with Changes in Royalties

Analogously, royalties displays a negative, linear correlation. The NPV would be $2.02 billion if no royalties were payable, and decreases by about $260 million for every percent increase in royalties. Royalties impact the NPV significantly, as it pertains, and is applied, to revenue. Thus, even when FCF is negative, royalties are still applied. The final modifying factor under examination is the discount factor, portrayed in Figure 3-19.

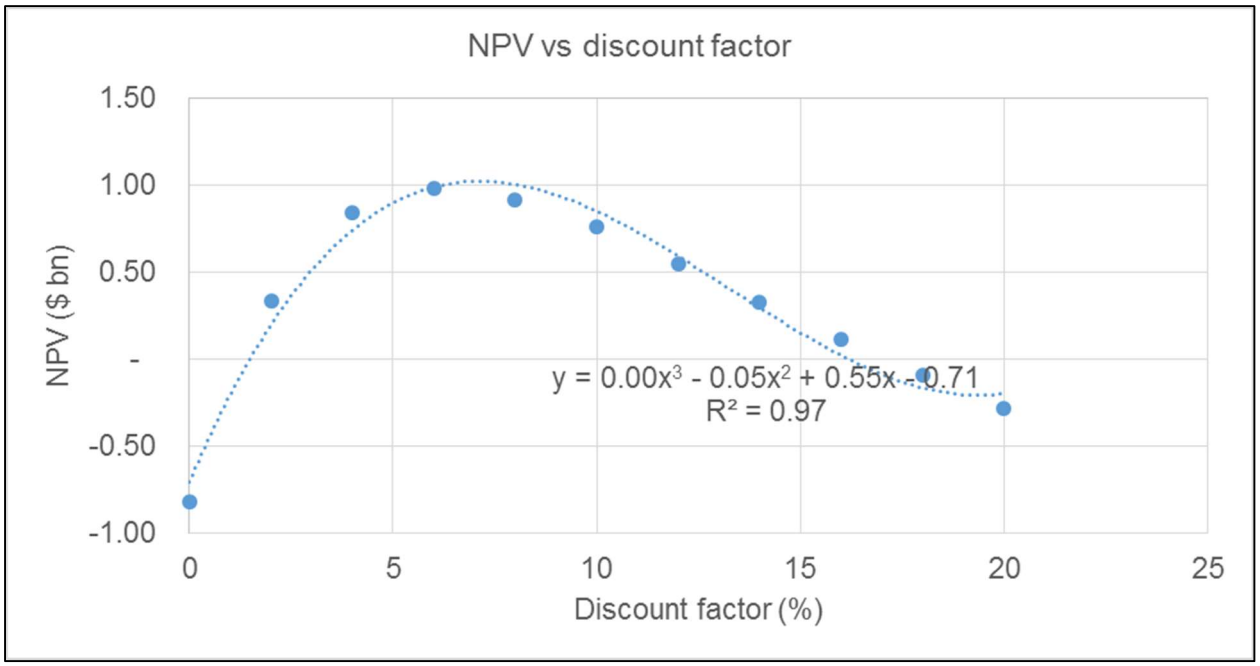

Figure 3-19: NPV Variation with Changes in Discount Factor

The discount factor is the only modifying factor discussed that is not linear (or close to linear). A third order polynomial had to be applied to get a correlation of $R^2 = 0.97$. This engenders it difficult to precisely determine the impact of a percentage point change. It is apparent that the NPV increases initially and then starts to decline as the discount factor increases. With no discount factor applied the NPV would be negative (-$0.82 billion). This is the only modifying factor where the NPV would be negative if the modifying factor is not applied. The greatest NPV is achieved at a discount factor of approximately 6.25%, where the NPV would be $0.98 billion. After the initial increase in NPV, the NPV again decreases to zero at a discount factor of approximately 17.08%.

It can be speculated that the discount factor is strongly influenced by the time value of money. An investigation into the FCFs renders three groups, viz. negative initial FCFs from year one to year three; positive FCFs during years four to nineteen; and again negative FCFs in the period of years twenty to twenty six. At a low discount factor, below 1.25%, the negative FCFs at end of LOM engender the NPV to be negative. At a high discount factor, above 17.08%, the initial negative

FCFs also render the NPV negative. With the discount factor between 1.25% and 17.08% the positive FCFs cause the NPV to be positive. This occurrence needs to be investigated in further detail to determine the true cause of the non-linear correlation. Table 3-10 encapsulates the economic modifying factors.

Table 3-10: Economic Modifying Factors

DESCRIPTION	MODEL VALUE	m-VALUE	NPV IF ZERO ($ bn)	NPV ZERO INTERSECTION (%)
Variable mining cost	20*	0.78	14.60	20.97*
Royalties	5	0.26	2.02	7.92
Variable processing cost	20*	0.20	4.65	23.75*
Discount factor	10	N/A	-0.82**	1.25 / 17.08**

** Dollar per tonne values*

*** Third order polynomial is not calculated the same as linear values*

The columns used are equivalent to those presented above for Table 3-9. As per the mining modifying factors, it is apparent that the m-value directly indicates the impact of the factor on the overall NPV, for the first three economic modifying factors. It is significant how close the model value and NPV zero intersection values are, indicating that minor changes could result in negative NPVs. The discount factor is the only modifying factor identified that does not linearly impact the NPV. The NPV of the project (all other factors kept constant) is positive between discount factors of 1.25% and 17.08%. As discussed above, it is believed that the negative-positive-negative FCF causes the non-linear correlation. Further research is required to ensure it is applied correctly.

For this study, no economic modifying factors have been identified as controlling parameters. The ensuing section explicates the principal findings from the sensitivity analysis.

3.5 Discussion of sensitivity analysis

This section of the discourse revealed that the factors which can significantly impact the financial viability of a mining project are not confined exclusively to mining modifying factors. Certain economic modifying factors, also with generally assumed values, evince an even greater influence on the NPV.

The principle difference between mining and economic modifying factors is that the mining related facets are commonly applied in specialised mining software, for instance Deswik. Consequent to this is the previously discussed scenario, where the mine plan, as the input to the financial model, comprises a fixed data set. Therefore, it is deemed that the mining modifying factors utilised to derive the mine plan are studied in insufficient detail. The economic modifying factors, alternatively, can be altered easily and the impact assessed during the financial evaluation. In addition, the predominance of the economic modifying factors evaluated are not merely percentages. Without variable mining and processing costs no mining would be possible. Even royalties are strongly linked to the applied commodity price; a change in commodity price can alter the impact of the royalties.

The conclusion is that the mining modifying factors directly impact the NPV, yet they are applied in software that cannot be effortlessly tracked and audited. It has been established that their impact can be readily measured, as long as easy auditing of the mine plan and setup is ensured, consistent with Diering *et al.* (2012).

3.6 Conclusion

The opening section elucidated the general geological properties of a fictitious gold deposit. The deposit was scheduled and the results analysed, prior to the data being inputted into a financial model. The exploration of the case study has revealed that the financial viability of a mining project prominently depends on the magnitude of the applied modifying factors. The fictitious gold deposit, utilised in this section, yielded a positive NPV. In practice this might lead to further study and eventual execution.

The sensitivity analysis conducted exposed that minimal changes to various mining modifying factors may result in a negative NPV. In this study, all the mining modifying factors exhibited a negative, linear correlation to the NPV. The impact on the NPV is strongly correlated to the m-value of the respective data sets. Three controlling parameters were identified, viz. plant yield loss; mining loss; and oversize. Minimal changes to any of these could lead to the project being suspended, scrapped or sold.

Additionally, particular economic modifying factors were evaluated to determine their impact on financial viability. It was concluded that, in certain instances, these factors had an even greater impact on the NPV than the mining modifying factors. It was found that the economic modifying factors can be more readily adjusted, thus posing a potentially smaller threat to financial viability. The most focal finding is that no modifying factor should be seen as trivial and the impact thereof, on financial viability, should be carefully studied.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

This chapter concludes the study and discusses three principal topics. The first section comprises conclusions and recommendations apropos the study. This section links the literature to the case study and highlights a few central facets. The second section reviews the objectives of the study, discussing each objective and evaluating whether it was achieved. The third section will advocate recommendations for future studies, highlighting certain areas that require further investigation and attention.

4.2 Conclusions and recommendations

The resource-to-reserve process is a critical component in ascertaining the future of a mining project. During this process a mine plan is derived, sequentially constituting the input to the financial model. The conclusion from the financial model, financial viability or not, determines whether the project is pursued or, alternatively parked, scrapped or sold.

The study finds that the modifying factors play a significant role in determining the financial viability of a mining project. The case study applied the modifying factors in a different manner to generally accepted practice.

The majority of studies include all the mining modifying factors in specialised mining software (for instance, the Deswik Software Suite, utilised for part of the case study). The resource-to-reserve material is calculated in this software. Due to this, only a single value for each modifying factor is applied. When utilising mining software, the ore volumes (reserve as reported in the mine plan) are calculated to yield a single data set that is not readily editable or auditable. These ore volumes are consecutively inputs into the financial model. As the ore volumes are reported as a fixed data set, sensitivity analyses are rendered extremely difficult to conduct.

Within this research, a different approach was followed. A portion of the resource-to-reserve process was performed in mining software, while the rest was modelled in MS Excel. This allowed sensitivity analysis to be performed on the four mining modifying factors applied, viz. plant yield loss; mining loss; oversize; and dilution.

Three of these modifying factors were identified as controlling parameters (per Rendu, 2002). This connotes that they critically impact the financial viability of the mining project. Slight alterations in any of these factors may lead to an unfavourable outcome, i.e. the project might not be financially viable.

Only a few modifying factors (four mining and four economic) were analysed during the study. In order to have a better understanding of the impact of different types of modifying factors, it is recommended that more modifying factors are evaluated and explored. Furthermore, it is advocated that the resource-to-reserve process should be reinvestigated by SAMREC. The aim should be to determine whether it would be beneficial to introduce stricter guidelines for the conversion process.

Auditability (as per Diering *et al.*, 2012) has also been identified as an integral component of an effective resource-to-reserve process. As mentioned, the reserve was predominantly calculated in MS Excel. This provides an open and easy to understand structure, which is readily auditable. For the purposes of this investigation the resource-to-reserve process was directly integrated into the financial model. This allows for a thorough audit to be conducted from the resource-to-reserve process to the final NPV (identified as the key financial indicator). In addition to the preceding suggestions, it is recommended SAMREC readdresses the auditability requirements. The subsequent section reviews the achievement of the objectives of the study.

4.3 Achievement of the objectives of the study

This study has focussed strongly on the impact of mining modifying factors. The objectives of the study (as per *1.3 - Objectives of the study*) have been met, as elucidated in the points below.

- The primary objective of this study is to investigate the impact of the qualitative reserve, and the process through which it is derived, on the quantitative financial model. The modifying factors will be investigated to evaluate their impact on the financial model and a project's eventual financial viability.

  Throughout the study the qualitative nature of the reserve has been apparent. All the factors applied have been based on interpretations from various data sources, inclusive of knowledge of the CP(s); values used by neighbouring projects; projects in the same commodity; etc. The case study identified three controlling parameters, viz. plant yield loss; mining losses; and oversize.

  The financial model built for the study exposed that it also includes certain qualitative fields, with variable costs for both mining and processing; royalties; and discount factor identified as prominent factors. These economic modifying factors significantly impact the financial viability of the mining project. The two areas in which the application of the economic modifying factors differs from the mining modifying factors are: dependent on reserve estimation and ease of editing.

The predominance of economic modifying factors (factors measured in dollars) are calculated based on the findings made during the reserve calculations, i.e. they are directly dependent on the size of the reserve. The infrastructure, personnel compliment, equipment requirements, etc. alter as the size of the reserve changes. Contrastingly, the mining modifying factors remain the same, irrespective of reserve size, as they are all percentages.

Ease of editing denotes that the financial model is arranged with a set of input values. These input values can be amended with ease and the impact on the NPV immediately measured. This allows for some adjustments during the financial analysis. Divergent to this, in practice, the reserve will generally be provided in tabular format with a set of values (such as a comma delimited/CSV data sheet). As previously stated, the reserve is usually scheduled in specialised mining software, wherein the mining modifying factors cannot be edited and manipulated by financial analysts.

Although the financial model evinces qualitative elements, the flow of the financial model remains quantitative. This still supports the primary objective that a qualitative reserve is fed into a quantitative financial model.

The case study clearly indicated the massive impact that changes in the controlling parameters exert on the financial viability of the mining project. Plant yield loss was applied as 15%. The critical value at which the plant yield loss would have made the project unfeasible is 17.83%. Had the original assumption been 20%, the NPV would have been negative and the project deemed unprofitable. Analogously, the same can be noted for mining losses (applied as 10%) and oversize (applied as 5%), these factors have critical values of 13.65% and 8.9%, respectively. These findings sufficiently address the primary objective.

Additionally, the secondary objectives were also addressed.

- Determining the major modifying factors that should be considered when transforming a resource into a reserve.

  The resource-to-reserve process is dependent on the logic and knowledge of the CP. The CP can apply generic modifying factors (the process followed for this study), or add additional factors based on prior knowledge and experience, for instance the financial worth of forests discussed by Temper and Martinez-Alier (2013). During the resource-to-reserve process this study identified four mining modifying factors, of which three were identified as controlling parameters;

- Investigating the link between the qualitative reserve model and quantitative financial model.

  The link between the models has been identified as the reserve output, which constitutes an input into the financial model. The output is obtained during the resource-to-reserve process, while the financial model calculates the eventual financial viability of the mining project;

- Establishing the impact of minor changes in the modifying factors on the financial viability of a mining project.

  The case study determined that minor changes to the three controlling parameters have significant impact on the financial viability of the project. The controlling parameters were all applied as generic values, common during early stage studies. With these values the project showed a positive NPV. It was determined that any of these values may have been applied as a slightly higher number (perhaps based on the CP's experience). If this were so, a smaller reserve would have been conveyed to the financial analysts and a negative NPV could have been obtained. In certain instances companies study multiple projects simultaneously, consequently, a negative NPV could result in a project being parked, scrapped or sold; and

- Exploring the manipulative ability of the resource-to-reserve process, as measured on the NPV.

  The NPV has been identified as the final output of the financial model. Any changes made to the resource-to-reserve process' input data directly impacts on the NPV. For this case study, the mine plan, as the output of the resource-to-reserve process, directly feeds into the financial model. This allows the impact of any changes to the mining modifying factors to be directly measurable on the NPV. Sensitivity analysis was used to study this impact. The study established that the mining modifying factors impact the NPV with varying magnitudes. The three mining modifying factors that yielded the greatest impact were identified as the controlling parameters for this study.

The primary and secondary objectives of the study were all successfully addressed.

4.4 Recommendations for further studies

Certain primary recommendations are emphasised below.

- The case study conducted was based on a fictitious gold deposit. Other commodities should be investigated to determine whether the same sensitivity is evident throughout different commodities. A manner by which this could be accomplished is to compile resource and reserve statements for various operations, across commodities. These data sets can be analysed and different ranges determined for the modifying factors applied in the studies.

These modifying factor ranges can then be related to the resources of the projects and the variations in project NPVs calculated;

- The case study did not allow for the conversion from a specific type of resource (i.e. inferred, indicated or measured) to a specific reserve (i.e. probable or proved). The case study made use of commonly applied values for the modifying factors. The work conducted by Macfarlane (2002) and the resource-to-reserve table in the SAMREC Code (SAMREC, 2009) could be beneficial when determining the range of values with which to test the modifying factors;

- For this case study the geological data was assumed accurate. This study focused on the link between the resource and the reserve. A similar study can be conducted for the derivation of the geological model. The principal focus of this type of study could constitute ore grade variations, as identified by Evatt *et al*. (2011);

- The orebody in the case study also contained other minerals (silver and lead). Most projects have multiple economic minerals present in the ore. The other minerals (excluding the primary mineral) are usually present in much smaller quantities (as was the case in the case study). As a result of their low quantities these other minerals are frequently not considered during economic evaluations. Njowa (2008) identified this as a possible area where additional revenue could be generated. It is recommended that careful attention is paid to these 'secondary' minerals and the impact they can have on the NPV; and

- In the case study the production tempo was applied to the mineable material. The central difference, when compared to projects in practice, is that the production tempo is normally linked to the ROM material. If the mine plan is based on ROM material, it is anticipated that the LOM will be more sensitive to adaptations in the modifying factors. This scenario indicates an area that needs to be studied in further detail to determine whether the sensitivity analyses will yield fundamentally different results.

This section discussed certain core recommendations for further studies.

4.5 Summary

The conclusions of the study reveal that three of the four modifying factors are controlling parameters, viz. plant yield loss, mining losses and oversize. These parameters need to be carefully considered during the resource-to-reserve process. The progression of the resource-to-reserve process (as well as for the financial model) was structured to facilitate auditability. The financial indicator used comprised the NPV of the project. The impact of the controlling parameters is clearly measurable on the NPV.

The penultimate section of this chapter ascertained that the objectives of the study have been achieved. The qualitative resource, as determined via the resource-to-reserve process and the quantitative financial model were successfully integrated, with the impact on the NPV measured. Sensitivity analysis proved to be an appropriate tool for the assessment.

The third section advocated recommendations for further study, identifying particular areas that require further investigation, as elucidated in the succeeding points.

- The study should be replicated for different commodities, this will ascertain whether the same assumptions and findings hold true for other commodities;
- The type of resource and reserve should be considered when conducting the resource-to-reserve process;
- There are steps that occur before the resource is defined, and it is recommended that certain of these, for example the determination of the geological model, need to be investigated to define their controlling parameters;
- The impact of other minerals in the resource (and reserve) should be investigated, as they may impact the eventual NPV of the mining project; and
- The impact of applying the modifying factors in specialised mining software should be investigated to determine whether the same findings hold true; for instance, examining the impact of applying the production tempo to the ROM material.

BIBLIOGRAPHY

Beasley, C. A., & Pfleider, E. P. 1972. Profitability sensitivity analysis of a mining venture. Tenth international symposium on the application of computer methods in the mineral industry, Johannesburg. http://www.saimm.co.za/Conferences/Apcom72/109-Beasley.pdf Date of access: 9 Jul 2014.

Businessdictionary. 2014. Data analysis. www.businessdictionary.com/definition/data-analysis.html Date of access: 27 Nov 2014.

Camisani-Calzolari, F.A., Krige, D.G. & Dixon, J.R. 2000. The South African code for reporting of mineral resources and mineral reserves and the geostatistical implications involved. http://www.saimm.co.za/Conferences/DanieKrige/DGK50.pdf Date of access: 9 Jul 2014.

Clifford, J.A. 2005. Resource – reserve classification and reporting: A global perspective. Presentation for Universidad Catholica de Chile – Valparaiso. http://www.crirsco.com/global_perspective.pdf Date of access: 11 May 2015.

Creswell, J.W. 2014. Research design. 4th ed. http://www.sagepub.com/upm-data/55588_Chapter_1_Sample_Creswell_Research_Design_4e.pdf Date of access: 16 Nov 2014.

Diering, D.H., Anderson, D.C., Langwieder, G. & Smith, G.L. 2012. The basic resource equations (bre & br2re) – a new approach to the definition and reconciliation of mineral resources and reserves at Anglo American Platinum Ltd. http://www.saimm.co.za/Conferences/Pt2012/557-576_Diering.pdf Date of access: 19 Apr 2015.

Dimitrakopoulos, R., Martinez, L. & Ramazan, S. 2007. A maximum upside / minimum downside approach to the traditional optimization of open pit mine design. *Journal of mining science,* 43(1) 2007. http://link.springer.com/ Date of access: 12 May 2015.

Evatt, G.W., Johnson, P.V., Duck, P.W., Howell, S.D. & Moriarty, J. 2011. The expected lifetime of an extraction project. Proceedings of the royal society A 467 (2011). http://rspa.royalsocietypublishing.org/ Date of access: 12 May 2015.

Evatt, G.W., Soltan, M.O. & Johnson, P.V. 2012. Mineral reserves under price uncertainty. Resource policy 37 (2012), 340-345. http://www.sciencedirect.com/science/article/pii/S0301420712000219 Date of access: 16 Apr 2015.

Harmony. 2010. Annual report 2010, glossary of terms. https://www.harmony.co.za/assets/investors/reporting/annual-reports/2010/glossary.htm Date of access: 5 Oct 2015.

Macfarlane, A.S. 2002. A Code for the valuation of mineral properties and projects in South Africa. *The South African institute for mining and metallurgy*, January/February 2002. www.saimm.co.za/Journal/v102n01p037.pdf Date of access: 29 May 2015.

Morley, C., Snowden, V. & Day, D. 1999. Financial impact of resource/reserve uncertainty. *Journal of the South African institute of mining and metallurgy*, October-December 1999. http://www.saimm.co.za/Journal/v099n06p293.pdf Date of access: 1 Jul 2014.

Njowa, G. 2008. Salient issues in the reporting of mineral resources and mineral reserves in the vein and reef mining. The Southern African institute of mining and metallurgy – Narrow vein and reef 2008. http://www.saimm.co.za/Conferences/NarrowVein2008/19-Njowa.pdf Date of access: 12 May 2015.

Parhizkar, A., Ataei, M. & Moarefvand, P. 2012. A probabilistic model to improve reconciliation of estimated and actual grade in open-pit mining. *Arabian Journal of Geosciences*, 5:1279-1288 (2012). http://download-v2.springer.com/static/pdf/742/art%253A10.1007%252Fs12517-010-0275-2.pdf?token2=exp=1431501137~acl=%2Fstatic%2Fpdf%2F742%2Fart%25253A10.1007%25252Fs12517-010-0275-2.pdf*~hmac=425b9e5ec406de3e45ae03beec450c62055b30b0e9824c8b5440eda2587916ca Date of access: 13 May 2015.

Rendu, J-M. 2002. Geostatistical simulations for risk assessment and decision making: The mining industry perspective. *International journal of surface mining, reclamation and environment,* 16(2) 2002. http://www.tandfonline.com.nwulib.nwu.ac.za/doi/pdf/10.1076/ijsm.16.2.122.3399 Date of access: 12 May 2015.

Rossouw, D. Editor. 2003. Intellectual tools: Skills for the human sciences. 2nd ed. Pretoria: Van Schaik Publishers.

Samcode. 2015. www.samcode.co.za Date of access: 3 Jun 2015.

SAMI 2013/2014. South Africa's mineral industry 2013 – 2014. Department: Mineral resources. http://www.dmr.gov.za/publications/south-africas-mineral-industry-sami/summary/217-south-african-minerals-industry-sami/1803-south-africas-mineral-industrysami-2013-2014.html Date of access: 29 May 2015.

SAMREC (South African Mineral Resource Committee). 2009. The South African code for the reporting of exploration results, mineral resources and mineral reserves (The Samrec code). http://www.samcode.co.za/downloads/SAMREC2009.pdf Date of access: 2 Jul 2015.

Sayadi, A.R., Tavassoli, S.M.M., Monjezi, M & Rezaei, M. 2014. Application of neural networks to predict net present value in mining projects. *Arabian Journal of Geosciences,* (2014) 7:1067-1072. http://nwulib.nwu.ac.za/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eoah&AN=32216071 Date of access: 12 Apr 2015.

Seccatore, J., Marin, T., de Tomi, G. & Veiga, M. 2014. A practical approach for the management of resources and reserves in Small-Scale Mining. *Journal of Cleaner Production,* 84 (2014). http://www.sciencedirect.com/science/article/pii/S0959652613006343 Date of access: 16 Apr 2015.

Shuttleworth, M. 2008. Case Study Research Design. https://explorable.com/case-study-research-design Date of access: 5 Nov 2015.

Stephenson, P.R. & Weatherstone, N. 2006. Developments in international mineral resource and reserve reporting. www.crirsco.com Date of access: 11 May 2015.

Temper, L. & Martinez-Alier, J. 2013. The god of the mountain and Godavarman: Net Present Value, indigenous territorial rights and sacredness in a bauxite mining conflict in India. *Ecological Economics*, 96 (2013). http://ac.els-cdn.com/S0921800913002978/1-s2.0-S0921800913002978-main.pdf?_tid=6cf4ecb6-e115-11e4-bc61-00000aab0f27&acdnat=1428844466_44b3ff440aa1d408b8ae8b8581ca5fab Date of access: 12 Apr 2015.

USC. 2014. Organizing Your Social Sciences Research Paper: Types of Research Designs. http://libguides.usc.edu/content.php?pid=83009&sid=818072 Date of access: 16 Nov 2014.

Van der Merwe, A.J., Simposya, V. & Wanless, M. 2007. Updated mineral resource estimate for the Ruighoek and Tuschenkomst properties. http://www.platmin.com/downloads/tr/ruighoek%20_tuschenkomst_SRK_update_min_res15apr07.pdf Date of access: 9 Jul 2014.

Walliman, N.S.R. 2011. Research methods: The basics. New York, NY: Taylor & Francis.

Weatherstone, N. 2005. The role of the mineral reserve estimator in promoting sustainable development in the mining industry. *Applied earth science*, (Transactions of the Institute of Mining and Metallurgy incorporating the Ausimm proceedings B) 114 (2005). http://www.maneyonline.com/doi/abs/10.1179/037174505X45478 Date of access: 14 Apr 2015.

Weijermars, R. 2015. Natural resource wealth optimisation: A review of fiscal regimes and equitable agreements for petroleum and mineral extraction projects. *Natural resources research*.

http://nwulib.nwu.ac.za/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eoah&AN=34837167 Date of access: 12 Apr 2015.

Welman, C., Kruger, F. & Mitchell, B. 2011. Research Methodology. 3rd ed., 10th impression. Oxford University Press: South Africa.

Winterstetter, A., Laner, D., Rechberger, H. & Fellner, J. 2015. Framework for the evaluation of anthropogenic resources: A landfill mining case study – Resource or reserve? *Resources, Conservation and Recycling*, 96 (2015) 19–30. http://nwulib.nwu.ac.za/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eoah&AN=34801855 Date of access: 12 Apr 2015.

ANNEXURE – YEARLY MINE PLAN

Yearly production plan

				LOM total	Yearly average
	Year				
	Mineable tonnes	t/yr		2 765 636 889	**106 370 650**
Mining rate	Mineable waste	t/yr		1 990 592 154	**76 561 237**
	Mineable ore	t/yr		775 044 735	**29 809 413**
	Mineable tonnes remaining	t			**888 508 041**
	Stripping ratio	Waste:Ore		2.57	**3.21**
Ore	Mineable ore	t/yr		775 044 735	**29 809 413**
	Mineable gold grade	g/t		4.06	**4.06**
	Mineable gold content	t		3 147	**121**
	Mining losses		10	77 504 474	**2 980 941**
	Dilution		5	38 752 237	**1 490 471**
Run of Mine (ROM)	ROM ore			736 292 498	**28 318 942**
	ROM gold			2 832	**109**
	Oversize	%	5	36 814 625	**1 415 947**
	Plant feed				
	Ore	t		699 477 873	**26 902 995**
	Gold	t		2 691	**103**
	Gold grade	g/t		3.85	**3.85**
	Plant yield losses	%	15	404	**16**
	Plant product (gold)	t		2 287	**88**
	Plant product (gold)	g		**2 287 113 774**	**87 965 914**
	Plant product (gold)	oz	31.10	**73 532 415**	**2 828 170**

Financial Model

Revenue	Commodity price (Revenue)	$/oz	1 200	**88 238 898 385**	**3 393 803 784**
Costs	Capital	$	1 500 000 000	**1 500 000 000**	-
	Mining	$/yr		**56 612 737 784**	**2 177 412 992**
	Fixed	$/yr	50 000 000	**1 300 000 000**	**50 000 000**
	Variable	$/t	20	**55 312 737 784**	**2 127 412 992**
	Processing	$/yr		**14 769 557 467**	**568 059 903**
	Fixed	$/yr	30 000 000	**780 000 000**	**30 000 000**
	Variable	$/t	20	**13 989 557 467**	**538 059 903**
	Logistics	$/oz	100	**7 353 241 532**	**282 816 982**
	Total operating cash costs - excl. royalties	$/yr		**78 735 536 783**	**3 028 289 876**
	Total operating cash costs per oz sold	$/oz		**1 071**	**1 225**
	Total operating cash costs per tonne mined	$/t		**28.47**	**28.44**
	Royalties	% of revenue	5	**4 411 944 919**	**169 690 189**
	Total operating cash costs	$/yr		**83 147 481 702**	**3 197 980 065**
	Total operating cash costs per oz sold	$/oz		**1 131**	**1 285**
	Total operating cash costs per tonne mined	$/t		**30.06**	**30.02**
	EBITDA	$/yr		**5 091 416 683**	**195 823 719**
	Margin (% of Revenue)	%		**6**	**-7**
	Depreciation - N/A (Contractor)	%	0	0	0
	EBIT	$/yr		**5 091 416 683**	**195 823 719**
	Margin (% of Revenue)	%		**6**	**-7**
	EBIT			**5 091 416 683**	**195 823 719**
	Tax	%	35	**4 413 519 928**	**275 844 995**
	Depreciation			-	-
	Change in working capital		0		-
	Capex			**1 500 000 000**	**1 500 000 000**
	Free cash flow (FCF)			**-822 103 245**	**-31 619 356**
	Discount factor	%	10		**0**
	Discounted cash flow (DCF)				**29 101 558**
Value	NPV	$		**756 640 505**	

Year	1	2	3	4	5	6
Mineable tonnes	55 500 010	87 600 004	103 800 006	109 500 004	109 800 010	109 500 011
Mineable waste	42 460 236	67 576 975	79 891 959	75 675 031	69 838 456	72 918 097
Mineable ore	13 039 774	20 023 029	23 908 047	33 824 973	39 961 553	36 581 915
Mineable tonnes remaining	**2 710 136 880**	**2 622 536 876**	**2 518 736 870**	**2 409 236 866**	**2 299 436 856**	**2 189 936 845**
Stripping ratio	**3.26**	**3.37**	**3.34**	**2.24**	**1.75**	**1.99**
Mineable ore	13 039 774	20 023 029	23 908 047	33 824 973	39 961 553	36 581 915
Mineable gold grade	3.45	3.78	4.42	3.66	4.43	4.20
Mineable gold content	**44.94**	**75.70**	**105.68**	**123.73**	**177.20**	**153.63**
Mining losses	**1 303 977**	**2 002 303**	**2 390 805**	**3 382 497**	**3 996 155**	**3 658 191**
Dilution	**651 989**	**1 001 151**	**1 195 402**	**1 691 249**	**1 998 078**	**1 829 096**
ROM ore	**12 387 785**	**19 021 878**	**22 712 644**	**32 133 725**	**37 963 476**	**34 752 819**
ROM gold	**40.45**	**68.13**	**95.11**	**111.36**	**159.48**	**138.26**
Oversize	**619 389.24**	**951 093.88**	**1 135 632.21**	**1 606 686.23**	**1 898 173.78**	**1 737 640.95**
Plant feed						
Ore	**11 768 396**	**18 070 784**	**21 577 012**	**30 527 038**	**36 065 302**	**33 015 178**
Gold	**38.42**	**64.72**	**90.35**	**105.79**	**151.51**	**131.35**
Gold grade	**3.27**	**3.58**	**4.19**	**3.47**	**4.20**	**3.98**
Plant yield losses	**5.76**	**9.71**	**13.55**	**15.87**	**22.73**	**19.70**
Plant product (gold)	**32.66**	**55.01**	**76.80**	**89.92**	**128.78**	**111.65**
Plant product (gold)	**32 660 842**	**55 013 661**	**76 801 515**	**89 922 655**	**128 779 337**	**111 647 252**
Plant product (gold)	**1 050 070**	**1 768 730**	**2 469 226**	**2 891 080**	**4 140 352**	**3 589 543**

Commodity price (Revenue)	**1 260 084 557**	**2 122 476 319**	**2 963 071 237**	**3 469 296 593**	**4 968 422 182**	**4 307 451 019**
Capital	1 500 000 000					
Mining	**1 160 000 194**	**1 802 000 076**	**2 126 000 117**	**2 240 000 075**	**2 246 000 193**	**2 240 000 227**
Fixed	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**
Variable	**1 110 000 194**	**1 752 000 076**	**2 076 000 117**	**2 190 000 075**	**2 196 000 193**	**2 190 000 227**
Processing	**265 367 913**	**391 415 676**	**461 540 241**	**640 540 766**	**751 306 036**	**690 303 562**
Fixed	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**
Variable	**235 367 913**	**361 415 676**	**431 540 241**	**610 540 766**	**721 306 036**	**660 303 562**
Logistics	**105 007 046**	**176 873 027**	**246 922 603**	**289 108 049**	**414 035 182**	**358 954 252**
Total operating cash costs - excl. royalties	**1 530 375 153**	**2 370 288 778**	**2 834 462 961**	**3 169 648 891**	**3 411 341 411**	**3 289 258 041**
Total operating cash costs per oz sold	**1 457**	**1 340**	**1 148**	**1 096**	**824**	**916**
Total operating cash costs per tonne mined	**27.57**	**27.06**	**27.31**	**28.95**	**31.07**	**30.04**
Royalties	**63 004 228**	**106 123 816**	**148 153 562**	**173 464 830**	**248 421 109**	**215 372 551**
Total operating cash costs	**1 593 379 381**	**2 476 412 594**	**2 982 616 523**	**3 343 113 720**	**3 659 762 520**	**3 504 630 592**
Total operating cash costs per oz sold	**1 517**	**1 400**	**1 208**	**1 156**	**884**	**976**
Total operating cash costs per tonne mined	**28.71**	**28.27**	**28.73**	**30.53**	**33.33**	**32.01**
EBITDA	**-333 294 823**	**-353 936 275**	**-19 545 286**	**126 182 873**	**1 308 659 662**	**802 820 427**
Margin (% of Revenue)	**-26.45**	**-16.68**	**-0.66**	**3.64**	**26.34**	**18.64**
Depreciation - N/A (Contractor)	0	0	0	0	0	0
EBIT	-333 294 823	-353 936 275	-19 545 286	126 182 873	1 308 659 662	802 820 427
Margin (% of Revenue)	**-26.45**	**-16.68**	**-0.66**	**3.64**	**26.34**	**18.64**
EBIT	-333 294 823	-353 936 275	-19 545 286	126 182 873	1 308 659 662	802 820 427
Tax	**-**	**-**	**-**	**44 164 006**	**458 030 882**	**280 987 150**
Depreciation	0	0	0	0	0	0
Change in working capital						
Capex	1 500 000 000	-	-	-	-	-
Free cash flow (FCF)	**-1 833 294 823**	**-353 936 275**	**-19 545 286**	**82 018 867**	**850 628 780**	**521 833 278**
Discount factor	**1.00**	**0.91**	**0.83**	**0.75**	**0.68**	**0.62**
Discounted cash flow (DCF)	**-1 833 294 823**	**-321 760 250**	**-16 153 129**	**61 621 989**	**580 990 902**	**324 017 409**
NPV						

Year	7	8	9	10	11	12
Mineable tonnes	109 499 977	109 500 003	109 799 995	109 500 014	109 499 988	109 500 009
Mineable waste	77 607 669	70 092 594	64 727 580	67 841 502	71 176 566	71 599 684
Mineable ore	31 892 308	39 407 409	45 072 415	41 658 512	38 323 423	37 900 325
Mineable tonnes remaining	2 080 436 868	1 970 936 865	1 861 136 869	1 751 636 856	1 642 136 867	1 532 636 859
Stripping ratio	2.43	1.78	1.44	1.63	1.86	1.89
Mineable ore	31 892 308	39 407 409	45 072 415	41 658 512	38 323 423	37 900 325
Mineable gold grade	5.91	4.31	4.18	4.38	4.52	4.18
Mineable gold content	188.36	169.99	188.21	182.67	173.25	158.35
Mining losses	3 189 231	3 940 741	4 507 242	4 165 851	3 832 342	3 790 032
Dilution	1 594 615	1 970 370	2 253 621	2 082 926	1 916 171	1 895 016
ROM ore	30 297 693	37 437 038	42 818 794	39 575 586	36 407 251	36 005 308
ROM gold	169.52	153.00	169.38	164.40	155.93	142.52
Oversize	1 514 884.63	1 871 851.91	2 140 939.72	1 978 779.31	1 820 362.57	1 800 265.42
Plant feed						
Ore	28 782 808	35 565 186	40 677 855	37 596 807	34 586 889	34 205 043
Gold	161.05	145.35	160.92	156.18	148.13	135.39
Gold grade	5.60	4.09	3.96	4.15	4.28	3.96
Plant yield losses	24.16	21.80	24.14	23.43	22.22	20.31
Plant product (gold)	136.89	123.54	136.78	132.76	125.91	115.08
Plant product (gold)	136 889 806	123 543 495	136 778 275	132 755 322	125 911 654	115 081 170
Plant product (gold)	4 401 109	3 972 016	4 397 524	4 268 183	4 048 154	3 699 946
Commodity price (Revenue)	5 281 331 341	4 766 418 726	5 277 028 388	5 121 819 248	4 857 784 408	4 439 934 635
Capital						
Mining	2 239 999 548	2 240 000 059	2 245 999 906	2 240 000 274	2 239 999 766	2 240 000 176
Fixed	50 000 000	50 000 000	50 000 000	50 000 000	50 000 000	50 000 000
Variable	2 189 999 548	2 190 000 059	2 195 999 906	2 190 000 274	2 189 999 766	2 190 000 176
Processing	605 656 159	741 303 725	843 557 093	781 936 138	721 737 778	714 100 858
Fixed	30 000 000	30 000 000	30 000 000	30 000 000	30 000 000	30 000 000
Variable	575 656 159	711 303 725	813 557 093	751 936 138	691 737 778	684 100 858
Logistics	440 110 945	397 201 560	439 752 366	426 818 271	404 815 367	369 994 553
Total operating cash costs - excl. royalties	3 285 766 652	3 378 505 344	3 529 309 365	3 448 754 683	3 366 552 911	3 324 095 587
Total operating cash costs per oz sold	747	851	803	808	832	898
Total operating cash costs per tonne mined	30.01	30.85	32.14	31.50	30.74	30.36
Royalties	264 066 567	238 320 936	263 851 419	256 090 962	242 889 220	221 996 732
Total operating cash costs	3 549 833 219	3 616 826 281	3 793 160 785	3 704 845 645	3 609 442 132	3 546 092 319
Total operating cash costs per oz sold	807	911	863	868	892	958
Total operating cash costs per tonne mined	32.42	33.03	34.55	33.83	32.96	32.38
EBITDA	1 731 498 122	1 149 592 445	1 483 867 603	1 416 973 603	1 248 342 277	893 842 317
Margin (% of Revenue)	32.79	24.12	28.12	27.67	25.70	20.13
Depreciation - N/A (Contractor)	0	0	0	0	0	0
EBIT	1 731 498 122	1 149 592 445	1 483 867 603	1 416 973 603	1 248 342 277	893 842 317
Margin (% of Revenue)	32.79	24.12	28.12	27.67	25.70	20.13
EBIT	1 731 498 122	1 149 592 445	1 483 867 603	1 416 973 603	1 248 342 277	893 842 317
Tax	606 024 343	402 357 356	519 353 661	495 940 761	436 919 797	312 844 811
Depreciation	0	0	0	0	0	0
Change in working capital						
Capex	-	-	-	-	-	-
Free cash flow (FCF)	1 125 473 779	747 235 089	964 513 942	921 032 842	811 422 480	580 997 506
Discount factor	0.56	0.51	0.47	0.42	0.39	0.35
Discounted cash flow (DCF)	635 300 607	383 449 752	449 952 872	390 607 835	312 838 492	203 636 081
NPV						

Year	13	14	15	16	17	18
Mineable tonnes	109 800 004	109 500 006	109 499 984	109 499 995	109 799 999	109 499 984
Mineable waste	85 410 795	72 817 693	77 803 547	77 247 604	75 744 933	70 213 730
Mineable ore	24 389 209	36 682 313	31 696 437	32 252 391	34 055 066	39 286 254
Mineable tonnes remaining	**1 422 836 855**	**1 313 336 849**	**1 203 836 865**	**1 094 336 870**	**984 536 872**	**875 036 888**
Stripping ratio	**3.50**	**1.99**	**2.45**	**2.40**	**2.22**	**1.79**
Mineable ore	24 389 209	36 682 313	31 696 437	32 252 391	34 055 066	39 286 254
Mineable gold grade	5.14	4.03	4.06	3.82	3.84	3.25
Mineable gold content	**125.35**	**147.67**	**128.81**	**123.05**	**130.85**	**127.52**
Mining losses	**2 438 921**	**3 668 231**	**3 169 644**	**3 225 239**	**3 405 507**	**3 928 625**
Dilution	**1 219 460**	**1 834 116**	**1 584 822**	**1 612 620**	**1 702 753**	**1 964 313**
ROM ore	**23 169 749**	**34 848 197**	**30 111 615**	**30 639 772**	**32 352 313**	**37 321 941**
ROM gold	**112.82**	**132.90**	**115.93**	**110.75**	**117.77**	**114.76**
Oversize	**1 158 487.44**	**1 742 409.85**	**1 505 580.74**	**1 531 988.58**	**1 617 615.63**	**1 866 097.05**
Plant feed						
Ore	**22 011 261**	**33 105 787**	**28 606 034**	**29 107 783**	**30 734 697**	**35 455 844**
Gold	**107.18**	**126.26**	**110.14**	**105.21**	**111.88**	**109.03**
Gold grade	**4.87**	**3.81**	**3.85**	**3.61**	**3.64**	**3.07**
Plant yield losses	**16.08**	**18.94**	**16.52**	**15.78**	**16.78**	**16.35**
Plant product (gold)	**91.10**	**107.32**	**93.62**	**89.43**	**95.10**	**92.67**
Plant product (gold)	**91 101 346**	**107 319 826**	**93 615 423**	**89 427 363**	**95 097 233**	**92 671 758**
Plant product (gold)	**2 928 976**	**3 450 413**	**3 009 806**	**2 875 156**	**3 057 447**	**2 979 466**
Commodity price (Revenue)	**3 514 771 539**	**4 140 495 037**	**3 611 766 896**	**3 450 187 762**	**3 668 936 450**	**3 575 359 431**
Capital						
Mining	**2 246 000 084**	**2 240 000 114**	**2 239 999 670**	**2 239 999 900**	**2 245 999 973**	**2 239 999 671**
Fixed	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**
Variable	**2 196 000 084**	**2 190 000 114**	**2 189 999 670**	**2 189 999 900**	**2 195 999 973**	**2 189 999 671**
Processing	**470 225 226**	**692 115 742**	**602 120 681**	**612 155 662**	**644 693 939**	**739 116 879**
Fixed	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**
Variable	**440 225 226**	**662 115 742**	**572 120 681**	**582 155 662**	**614 693 939**	**709 116 879**
Logistics	**292 897 628**	**345 041 253**	**300 980 575**	**287 515 647**	**305 744 704**	**297 946 619**
Total operating cash costs - excl. royalties	**3 009 122 938**	**3 277 157 109**	**3 143 100 926**	**3 139 671 208**	**3 196 438 617**	**3 277 063 170**
Total operating cash costs per oz sold	**1 027**	**950**	**1 044**	**1 092**	**1 045**	**1 100**
Total operating cash costs per tonne mined	**27.41**	**29.93**	**28.70**	**28.67**	**29.11**	**29.93**
Royalties	**175 738 577**	**207 024 752**	**180 588 345**	**172 509 388**	**183 446 823**	**178 767 972**
Total operating cash costs	**3 184 861 515**	**3 484 181 861**	**3 323 689 271**	**3 312 180 596**	**3 379 885 439**	**3 455 831 141**
Total operating cash costs per oz sold	**1 087**	**1 010**	**1 104**	**1 152**	**1 105**	**1 160**
Total operating cash costs per tonne mined	**29.01**	**31.82**	**30.35**	**30.25**	**30.78**	**31.56**
EBITDA	**329 910 024**	**656 313 177**	**288 077 625**	**138 007 165**	**289 051 011**	**119 528 290**
Margin (% of Revenue)	**9.39**	**15.85**	**7.98**	**4.00**	**7.88**	**3.34**
Depreciation - N/A (Contractor)	0	0	0	0	0	0
EBIT	329 910 024	656 313 177	288 077 625	138 007 165	289 051 011	119 528 290
Margin (% of Revenue)	**9.39**	**15.85**	**7.98**	**4.00**	**7.88**	**3.34**
EBIT	329 910 024	656 313 177	288 077 625	138 007 165	289 051 011	119 528 290
Tax	**115 468 508**	**229 709 612**	**100 827 169**	**48 302 508**	**101 167 854**	**41 834 901**
Depreciation	0	0	0	0	0	0
Change in working capital						
Capex	-	-	-	-	-	-
Free cash flow (FCF)	**214 441 515**	**426 603 565**	**187 250 457**	**89 704 658**	**187 883 157**	**77 693 388**
Discount factor	**0.32**	**0.29**	**0.26**	**0.24**	**0.22**	**0.20**
Discounted cash flow (DCF)	**68 327 675**	**123 571 857**	**49 308 898**	**21 474 582**	**40 888 849**	**15 371 223**
NPV						

Year	19	20	21	22	23	24
Mineable tonnes	109 499 996	109 499 994	109 800 016	109 500 008	109 500 017	109 500 018
Mineable waste	67 811 436	75 020 280	85 980 360	89 985 779	90 899 157	94 527 853
Mineable ore	41 688 561	34 479 714	23 819 656	19 514 230	18 600 861	14 972 165
Mineable tonnes remaining	**765 536 892**	**656 036 897**	**546 236 882**	**436 736 873**	**327 236 856**	**217 736 838**
Stripping ratio	**1.63**	**2.18**	**3.61**	**4.61**	**4.89**	**6.31**
Mineable ore	41 688 561	34 479 714	23 819 656	19 514 230	18 600 861	14 972 165
Mineable gold grade	3.60	3.15	3.13	3.38	3.42	3.62
Mineable gold content	**150.20**	**108.54**	**74.63**	**66.01**	**63.63**	**54.22**
Mining losses	**4 168 856**	**3 447 971**	**2 381 966**	**1 951 423**	**1 860 086**	**1 497 217**
Dilution	**2 084 428**	**1 723 986**	**1 190 983**	**975 711**	**930 043**	**748 608**
ROM ore	**39 604 133**	**32 755 729**	**22 628 673**	**18 538 518**	**17 670 818**	**14 223 557**
ROM gold	**135.18**	**97.68**	**67.17**	**59.41**	**57.27**	**48.80**
Oversize	**1 980 206.65**	**1 637 786.43**	**1 131 433.64**	**926 925.90**	**883 540.89**	**711 177.85**
Plant feed						
Ore	**37 623 926**	**31 117 942**	**21 497 239**	**17 611 592**	**16 787 277**	**13 512 379**
Gold	**128.42**	**92.80**	**63.81**	**56.44**	**54.40**	**46.36**
Gold grade	**3.41**	**2.98**	**2.97**	**3.20**	**3.24**	**3.43**
Plant yield losses	**19.26**	**13.92**	**9.57**	**8.47**	**8.16**	**6.95**
Plant product (gold)	**109.16**	**78.88**	**54.24**	**47.98**	**46.24**	**39.40**
Plant product (gold)	**109 157 316**	**78 880 034**	**54 236 329**	**47 975 532**	**46 244 150**	**39 403 295**
Plant product (gold)	**3 509 489**	**2 536 052**	**1 743 738**	**1 542 449**	**1 486 784**	**1 266 845**
Commodity price (Revenue)	**4 211 387 043**	**3 043 262 380**	**2 092 486 159**	**1 850 938 994**	**1 784 140 721**	**1 520 214 430**
Capital						
Mining	**2 239 999 930**	**2 239 999 886**	**2 246 000 313**	**2 240 000 164**	**2 240 000 350**	**2 240 000 355**
Fixed	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**	**50 000 000**
Variable	**2 189 999 930**	**2 189 999 886**	**2 196 000 313**	**2 190 000 164**	**2 190 000 350**	**2 190 000 355**
Processing	**782 478 525**	**652 358 842**	**459 944 784**	**382 231 843**	**365 745 539**	**300 247 582**
Fixed	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**	**30 000 000**
Variable	**752 478 525**	**622 358 842**	**429 944 784**	**352 231 843**	**335 745 539**	**270 247 582**
Logistics	**350 948 920**	**253 605 198**	**174 373 847**	**154 244 916**	**148 678 393**	**126 684 536**
Total operating cash costs - excl. royalties	**3 373 427 375**	**3 145 963 927**	**2 880 318 943**	**2 776 476 923**	**2 754 424 282**	**2 666 932 473**
Total operating cash costs per oz sold	**961**	**1 240**	**1 652**	**1 800**	**1 853**	**2 105**
Total operating cash costs per tonne mined	**30.81**	**28.73**	**26.23**	**25.36**	**25.15**	**24.36**
Royalties	**210 569 352**	**152 163 119**	**104 624 308**	**92 546 950**	**89 207 036**	**76 010 722**
Total operating cash costs	**3 583 996 727**	**3 298 127 046**	**2 984 943 251**	**2 869 023 873**	**2 843 631 318**	**2 742 943 194**
Total operating cash costs per oz sold	**1 021**	**1 300**	**1 712**	**1 860**	**1 913**	**2 165**
Total operating cash costs per tonne mined	**32.73**	**30.12**	**27.19**	**26.20**	**25.97**	**25.05**
EBITDA	**627 390 315**	**-254 864 666**	**-892 457 092**	**-1 018 084 879**	**-1 059 490 597**	**-1 222 728 764**
Margin (% of Revenue)	**14.90**	**-8.37**	**-42.65**	**-55.00**	**-59.38**	**-80.43**
Depreciation - N/A (Contractor)	0	0	0	0	0	0
EBIT	627 390 315	-254 864 666	-892 457 092	-1 018 084 879	-1 059 490 597	-1 222 728 764
Margin (% of Revenue)	**14.90**	**-8.37**	**-42.65**	**-55.00**	**-59.38**	**-80.43**
EBIT	627 390 315	-254 864 666	-892 457 092	-1 018 084 879	-1 059 490 597	-1 222 728 764
Tax	**219 586 610**	**-**	**-**	**-**	**-**	**-**
Depreciation	0	0	0	0	0	0
Change in working capital						
Capex	-	-	-	-	-	-
Free cash flow (FCF)	**407 803 705**	**-254 864 666**	**-892 457 092**	**-1 018 084 879**	**-1 059 490 597**	**-1 222 728 764**
Discount factor	**0.18**	**0.16**	**0.15**	**0.14**	**0.12**	**0.11**
Discounted cash flow (DCF)	**73 347 081**	**-41 672 409**	**-132 658 060**	**-137 574 391**	**-130 154 154**	**-136 552 096**
NPV						

Year	25	26
Mineable tonnes	109 799 999	107 936 839
Mineable waste	96 250 196	99 472 444
Mineable ore	13 549 803	8 464 395
Mineable tonnes remaining	**107 936 839**	**0**
Stripping ratio	**7.10**	**11.75**
Mineable ore	13 549 803	8 464 395
Mineable gold grade	4.35	5.42
Mineable gold content	**58.98**	**45.87**
Mining losses	**1 354 980**	**846 439**
Dilution	**677 490**	**423 220**
ROM ore	**12 872 313**	**8 041 175**
ROM gold	**53.08**	**41.29**
Oversize	**643 615.65**	**402 058.76**
Plant feed		
Ore	**12 228 697**	**7 639 116**
Gold	**50.42**	**39.22**
Gold grade	**4.12**	**5.13**
Plant yield losses	**7.56**	**5.88**
Plant product (gold)	**42.86**	**33.34**
Plant product (gold)	**42 861 142**	**33 338 044**
Plant product (gold)	**1 378 018**	**1 071 843**
Commodity price (Revenue)	**1 653 621 271**	**1 286 211 615**
Capital		
Mining	**2 245 999 984**	**2 208 736 779**
Fixed	**50 000 000**	**50 000 000**
Variable	**2 195 999 984**	**2 158 736 779**
Processing	**274 573 947**	**182 782 329**
Fixed	**30 000 000**	**30 000 000**
Variable	**244 573 947**	**152 782 329**
Logistics	**137 801 773**	**107 184 301**
Total operating cash costs - excl. royalties	**2 658 375 704**	**2 498 703 410**
Total operating cash costs per oz sold	**1 929**	**2 331**
Total operating cash costs per tonne mined	**24.21**	**23.15**
Royalties	**82 681 064**	**64 310 581**
Total operating cash costs	**2 741 056 767**	**2 563 013 991**
Total operating cash costs per oz sold	**1 989**	**2 391**
Total operating cash costs per tonne mined	**24.96**	**23.75**
EBITDA	**-1 087 435 496**	**-1 276 802 376**
Margin (% of Revenue)	**-65.76**	**-99.27**
Depreciation - N/A (Contractor)	0	0
EBIT	-1 087 435 496	-1 276 802 376
Margin (% of Revenue)	**-65.76**	**-99.27**
EBIT	-1 087 435 496	-1 276 802 376
Tax	**-**	**-**
Depreciation	0	0
Change in working capital		
Capex	-	-
Free cash flow (FCF)	**-1 087 435 496**	**-1 276 802 376**
Discount factor	**0.10**	**0.09**
Discounted cash flow (DCF)	**-110 402 539**	**-117 843 750**
NPV		