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AN ASSESSMENT OF THE LONG-TERM COMMODITY PRICE ASSUMPTIONS ON THE MINERAL RESERVE ESTIMATES OF SOUTH AFRICAN GOLD AND PLATINUM MINING COMPANIES FROM 2000 TO 2016

Vulani Maseko

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

Johannesburg, 2018

DECLARATION

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

Signed:

_____

Vulani Maseko

This ____ day of _____, 2018

ABSTRACT

In the 19th and 20th centuries mining underwent an evolution from the exploitation of small mining properties by individual claim holders to consolidation and the formation of multinational mining companies. With the rise of multinational mining companies came the advent of international finance in the mining industry. As companies developed and operated larger mining projects across several geographies, their capital requirements increased. As the number of investors in mining projects increased, through the raising of finance on international capital markets, so did the importance of mineral asset reporting. While governments and other organisations reported on the mineral inventories of countries, international mining companies had to report on only the economic portions of their mineral assets. The early days of international mineral asset reporting resulted in several reporting scandals where investors were misled by unscrupulous companies and individuals who reported false mineral deposit quantities and qualities in an attempt to manipulate investor sentiment for personal profit. As a result of these reporting scandals, the international mineral reporting codes were developed to increase the quality and transparency of mineral asset reporting and to protect investors. In the case of South Africa, the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC) Code, was first published in March 2000 and adopted by the Johannesburg Stock Exchange (JSE) later that year. The SAMREC Code, like the other international mineral reporting codes, aimed to ensure quality and transparent mineral asset reporting. Mineral Resources and Mineral Reserves are collectively a backbone asset for any company in the minerals industry

This research study assessed the reporting of Mineral Reserves in South Africa in the period from the introduction of the SAMREC Code, in 2000, to 2016, with specific focus on reporting by South Africa's gold and platinum mining companies. Mineral Reserve reporting was identified as a key focus, as Mineral Reserves are the economically mineable portions of Mineral Resources, and therefore give a better indication of the prospects of mining companies in the short to medium term. The literature review conducted as a part of this research study indicated that long-term commodity prices are the most important modifying factors used in Mineral Reserve

estimation, hence there was a specific focus on the long-term commodity prices used in the Mineral Reserve estimates of South Africa's gold and platinum mining companies. However, the relationships between the Mineral Reserve estimates and the other modifying factors were also assessed.

The research demonstrated a general improvement in the quality of Mineral Reserve reporting by South Africa's gold and platinum mining companies since the introduction of the SAMREC Code in 2000. However, the quality of Mineral Reserve reporting by the platinum mining companies was found be considerably less detailed to that of the gold mining companies. The long-term gold prices of the gold mining companies were found to be relatively conservative, often falling below prevailing spot prices, while the long-term prices of the platinum mining companies were often found to be more optimistic, with long-term platinum group metals (PGM) prices that were generally above prevailing spot prices. This research study also assessed the relationship between the Mineral Reserve estimates of South African gold and platinum mining companies and their reported modifying factors, with a specific focus on long-term commodity prices. The coefficient of determination (R^2) was used to assess the relationship between Mineral Reserve estimates and their associated modifying factors. The statistical analysis conducted demonstrated that the Mineral Reserves of South African gold and platinum mining companies between 2000 and 2016 were often most sensitive to changes in long-term commodity prices, relative to the other modifying factors.

The long-term commodity price assumptions of mining companies affect the value at which assets are recognised on their balance sheets. Sustained and fundamental differences between the long-term commodity price assumptions of mining companies and prevailing spot commodity prices may result in mining companies having to record impairments against their assets. In the period between 2000 and 2016, South African gold mining companies recognised a total of ZAR46bn (in nominal terms) in non-financial asset impairments, while platinum mining companies impaired their non-financial assets by a total of ZAR54bn. An assessment of the non-financial asset impairments of South Africa's platinum and

gold mining companies revealed that the least number of impairments were recorded when long-term commodity prices were within 5% of spot prices, suggesting that this should be the range within which long-term prices should be determined to limit future impairments.

DEDICATION

I dedicate this work to my parents, whose encouragement and guidance have been a strong driving force in my life.

To my wife and my two beautiful children, my efforts in this work and other endeavours are given purpose by your presence in my life.

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I would like to acknowledge the following individuals, whose contributions were critical in the completion of this research work:

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CONTENTS

DECLARATION i
ABSTRACT ii
DEDICATION v
ACKNOWLEDGEMENTS vi
LIST OF FIGURES ix
LIST OF TABLES xi
1 INTRODUCTION 1
1.1 Chapter overview 1
1.2 Research background 1
1.3 The South African mining industry 2
1.4 A brief history of the gold mining industry in South Africa 4
1.5 A brief history of the platinum mining industry in South Africa 8
1.6 A brief history of the international Mineral Resource and Mineral Reserve reporting codes and reporting scandals 12
1.7 Research hypothesis 15
1.8 Research objectives 16
1.9 Report structure 16
2 LITERATURE REVIEW 18
2.1 Chapter overview 18
2.2 Mineral Resource and Mineral Reserve reporting under the international mineral reporting codes 18
2.3 The Mineral Reserve estimation process 21
2.4 The importance of commodity price assumptions to the Mineral Reserve estimation process 23
2.5 Commodity price assumptions for Mineral Reserve versus Mineral Resource reporting 24
2.6 Pay limits and cut-off grades 25
2.7 Discounted cash flow (DCF) modelling 26
2.8 Commodity price movements over time 27

2.9 South African gold and platinum company practices and performance 30
3 RESEARCH METHODOLOGY 34
4 THE MINERAL RESERVE DECLARATIONS OF SOUTH AFRICAN GOLD AND PLATINUM MINING COMPANIES 35
4.1 Chapter overview....35
4.2 The quality of Mineral Reserve reporting by South African gold and platinum mining companies....35
4.2.1 South African gold mining company Mineral Reserve reporting quality 36
4.2.2 South African platinum mining company Mineral Reserve reporting quality....58
4.3 The commodity price assumptions of South African gold and platinum mining companies relative to historical spot prices 69
4.4 The relationship between Mineral Reserves, long-term commodity prices and other modifying factors 73
4.5 The ideal commodity price range for the Mineral Reserve estimates of South African gold and platinum mining companies 85
5 CONCLUSIONS AND RECOMMENDATIONS 91
5.1 Conclusions....91
5.2 Recommendations for future research work....92
6 REFERENCES....94

LIST OF FIGURES

Figure 1.1: South African gold production relative to global supply 7
Figure 1.2: Mining method used for extracting narrow reefs in the Witwatersrand Basin 8
Figure 1.3: South African platinum group metal mining companies as at December 2003 10
Figure 1.4: Section showing the main development of a typical platinum mine.....12
Figure 2.1: Relationship CRIRSCO and the international mineral reporting codes.....19
Figure 2.2: Relationship between Exploration Results, Mineral Resources and Mineral Reserves 20
Figure 2.3: The Ore Reserve estimation process 22
Figure 2.4: South African gold mining company Mineral Resource and Mineral Reserve price assumptions relative to spot prices 30
Figure 2.5: ZAR PGM basket compared to Lonmin PLC long-term real price assumptions (2006-2014).....31
Figure 2.6: Impala Platinum Mineral Reserve 2016 ZAR PGM basket prices compared long-term real price assumptions and consensus prices 32
Figure 2.7: South African gold production cost curve (2015).....33
Figure 2.8: Global platinum cost curve including capex (2014) 33
Figure 4.1: Historical gold and PGM spot prices 2000-2016 70
Figure 4.2: Long-term gold price assumptions relative to spot prices 2000-2016..71
Figure 4.3: Long-term platinum price assumptions relative to spot prices 2000-2016 72
Figure 4.4: Long-term PGM price assumptions relative to spot prices 2000-2016 73
Figure 4.5: Kopanang 2016 Mineral Resource sensitivity analysis.....75
Figure 4.6: Moab Khotsoong 2016 Mineral Resource sensitivity analysis 77
Figure 4.7: Mponeng 2016 Mineral Resource sensitivity analysis 78
Figure 4.8: Tau Tona 2016 Mineral Resource sensitivity analysis.....78
Figure 4.9: Surface Operations 2016 Mineral Resources sensitivity analysis 80

Figure 4.10: Long-term gold prices and gold mining company impairments 89
Figure 4.11: Long-term platinum prices and platinum mining company impairments.....90

LIST OF TABLES

Table 1.1: Income in the South African mining industry for 2012 and 2015 3
Table 1.2: Companies established in the early years of the South African gold mining industry 5
Table 1.3: Major South African gold mining industry restructuring events 5
Table 1.4: Gold physical accounts for South Africa, 1980–2009 (tonnes) 6
Table 1.5: World gold production and reserves (tonnes) 7
Table 1.6: PGM physical accounts for South Africa, 1980–2009 (tonnes) 11
Table 1.7: World platinum and palladium production and reserves (kilograms) 11
Table 2.1: Typical modifying factor components 22
Table 4.1: AGA: Total AGA Mineral Reserves 2000 - 2016 37
Table 4.2 AGA: Kopanang Mineral Reserves 2000-2016.....38
Table 4.3: AGA: Moab Khotsong Mineral Reserves 2000- 2016 39
Table 4.4: AGA: Great Noligwa Mineral Reserves 2000-2013 39
Table 4.5: AGA: Mponeng Mineral Reserves 2000-2016 40
Table 4.6: AGA: Tau Tona Mineral Reserves 2000-2016.....41
Table 4.7: AGA: Savuka Mineral Reserves 2000-2012 41
Table 4.8: AGA: Surface Operations Mineral Reserves 2000-2016 42
Table 4.9: AGA: Tau Lekoa Mineral Reserves 2000-2009 42
Table 4.10: Harmony: Total Harmony Mineral Reserves 2000-2016.....43
Table 4.11: Harmony: Kusasalethu Mineral Reserves 2001-2016 44
Table 4.12: Harmony: Kalgold Mineral Reserves 2000-2016 44
Table 4.13: Harmony: Tshepong Mineral Reserves 2005-2016 46
Table 4.14: Harmony: Phakisa Mineral Reserves 2005-2016 46
Table 4.15: Harmony: Bambanani Mineral Reserves 2005-2016 46
Table 4.16: Harmony: Joel Mineral Reserves 2005-2016 47
Table 4.17: Harmony: St Helena 8 Mineral Reserves 2005-2007 47
Table 4.18: Harmony: West Mineral Reserves 2005-2006 47
Table 4.19: Harmony: Free Gold Mineral Reserves 2002-2004 47

Table 4.20: Harmony: Unisel Mineral Reserves 2005-2016 48
Table 4.21: Harmony: Masimong Mineral Reserves 2005-2016.....48
Table 4.22: Harmony: Merriespruit Mineral Reserves 2005-2010 49
Table 4.23: Harmony: Harmony 2 Mineral Reserves 2005-2009.....49
Table 4.24: Harmony: Brand 3 Mineral Reserves 2005-2009 49
Table 4.25: Harmony: Free State Operations Mineral Reserves 2000-2004.....49
Table 4.26: Harmony: Free State Surface Operations Mineral Reserves 2002-2016 50
Table 4.27: Harmony: Doornkop Mineral Reserves 2005-2016.....51
Table 4.28: Harmony: Cooke Mineral Reserves 2005-2007.....51
Table 4.29: Harmony: Randfontein Operations Mineral Reserves 2000-2004 51
Table 4.30: Harmony: Randfontein Surface Stockpile Mineral Reserves 2000-2007 51
Table 4.31: Harmony: Target 1 Mineral Reserves 2004-2016.....52
Table 4.32: Harmony: Target 3 Mineral Reserves 2010-2014.....53
Table 4.33: Harmony: Evander Mineral Reserves 2000-2011.....53
Table 4.34: Harmony: Orkney Mineral Reserves 2003-2006 54
Table 4.35: Gold Fields: Total Gold Fields Mineral Reserves 2000-2016 55
Table 4.36: Gold Fields: South Deep Mineral Reserves 2007-2016.....55
Table 4.37: Gold Fields: Beatrix Mineral Reserves 2000-2011 55
Table 4.38: Gold Fields: Kloof-Driefontein Complex Mineral Reserves 2000-2011 56
Table 4.39: Sibanye: Total Sibanye Gold Mineral Reserves 2012-2016 56
Table 4.40: Sibanye: Beatrix Mineral Reserves 2012-2016 56
Table 4.41: Sibanye: Driefontein Mineral Reserves 2012-2016 57
Table 4.42: Sibanye: Kloof Mineral Reserves 2012-2016 57
Table 4.43: Sibanye: Cooke Mineral Reserves 2013-2016 57
Table 4.44: Sibanye: West Rand Tailings Retreatment Project Mineral Reserves 2013-2016 57
Table 4.45: Sibanye: De Bron Merriespruit Mineral Reserves 2013-2016.....57

Table 4.46: Sibanye: Burnstone Mineral Reserves 2015-2016 58
Table 4.47: Amplats: Total Amplats Mineral Reserves 2000-2016.....59
Table 4.48: Amplats: Merensky Reef Mineral Reserves 2000-2016.....59
Table 4.49: Amplats: UG2 Reef Mineral Reserves 2000-2016.....60
Table 4.50: Amplats: Platreef Mineral Reserves 2003-2016 60
Table 4.51: Amplats: Main Suphide Zone (MSZ) Mineral Reserves 2001-2016....60
Table 4.52: Northam: Total Northam Mineral Reserves 2000-2016 61
Table 4.53: Northam: Zondereinde Mine Mineral Reserves 2000-2016 62
Table 4.54: Northam: Booysendal North Mine Mineral Reserves 2010-2016.....62
Table 4.55: Northam: Booysendal South Mine Mineral Reserves 2016 62
Table 4.56: Northam: Pandora Mineral Reserves 2009-2016 62
Table 4.57: Northam: Dwaalkop Mineral Reserves 2010-2015 63
Table 4.58: Lonmin: Total Lonmin Mineral Reserves 2000-2016 63
Table 4.59: Lonmin: Marikana Mineral Reserves 2000-2016 64
Table 4.60: Lonmin: Pandora Mineral Reserves 2007-2016 64
Table 4.61: Lonmin: Tailings Dam Mineral Reserves 2013-2016 64
Table 4.62: Lonmin: Limpopo Mineral Reserves 2005-2016 64
Table 4.63: Implats: Total Implats Mineral Reserves 2000-2016.....66
Table 4.64: Implats: Impala Mineral Reserves 2000-2016 66
Table 4.65: Implats: Marula Mineral Reserves 2002-2016 66
Table 4.66: Implats: Two Rivers Mineral Reserves 2005-2016 67
Table 4.67: Implats: Zimplats Mineral Reserves 2003-2016 67
Table 4.68: Implats: Mimosa Mineral Reserves 2003-2016 67
Table 4.69: Implats: Afplats-Leeuwkop Mineral Reserves 2007-2008.....68
Table 4.70: Implats: Crocodile River Mineral Reserves 2000-2001.....68
Table 4.71: Sibanye: Total Sibanye Platinum Mineral Reserves 2015-2016.....68
Table 4.72: Sibanye: Rustenburg Mineral Reserves 2015-2016 68
Table 4.73: Sibanye: Kroondal Mineral Reserves 2015-2016 68
Table 4.74: Sibanye: Mimosa Mineral Reserves 2015-2016 69

Table 4.75: Historical gold and PGM prices 2000-2016 69
Table 4.76: Historical spot gold prices and long-term gold price assumptions 2000-2016 70
Table 4.77: Historical spot platinum prices and long-term gold price assumptions 2000-2016 72
Table 4.78: Rating scale for R^2 values for the linear relationship between Mineral Reserves and modifying factors 74
Table 4.79: R^2 values of the linear relationship between South African gold mining company Mineral Reserves and modifying factors 76
Table 4.80: R^2 values of the linear relationship between South African platinum mining company Mineral Reserves and modifying factors 84
Table 4.81: Long-term gold prices and gold mining company impairments.....88
Table 4.82: Long-term platinum prices and platinum mining company impairments.....90

1 INTRODUCTION

1.1 Chapter overview

This chapter presents the background to the research topic. Firstly, the relevance of commodity price assumptions in the declaration of Mineral Resources and Mineral Reserves is discussed, then the context of the research topic is introduced through a brief discussion of the South African mining industry. The history of the South African gold and platinum mining industries and the international Mineral Resource and Mineral Reserve reporting codes are further discussed for additional background. Lastly the research objectives are introduced.

1.2 Research background

Mining companies operate in an environment that involves considerable levels of risk and uncertainty. The uncertainty of mining operations begins during the discovery phase of the mining life cycle. The process of estimating the volume and quality of a mineral deposit involves risk due to the possibility of inaccurate estimates. It is often said that the actual quantity and quality of a mineral deposit is only known when it has been fully depleted. The development phase of the mining life cycle contains risks associated with the suitability of the selected mining and processing methods, the estimation of project operating and capital costs and the execution risk of project delivery against construction schedules. When a mining project enters the operational phase it is subject to execution risks associated with performance against its business plans and technical studies. Financial risks due to the possibility of unexpected changes to operational cost inputs are also a major factor. Even as mines approach closure, they are exposed to risks associated with the extent of environmental damage and the necessary rehabilitation processes and costs, relative to the initial environmental impact assessments conducted at the development phase of the mining life cycle.

In addition to the risks which have already been highlighted, the risk associated with the value of the commodities mining companies produce is also very significant. Mining companies are often price-takers, which means that they often do not have control over the prices of the commodities they sell; which are mostly controlled by

market forces. This means that mining companies are vulnerable to the fluctuations and volatility of commodity prices and therefore have limited certainty in forecasting their future financial performance; outside of volatility mitigation strategies such as hedging. It is within this environment of commodity price uncertainty, that mining companies have to make investment decisions, declare Mineral Resources and Mineral Reserves and secure funding. Mineral Resources and Mineral Reserves collectively are the most important assets for any company in the minerals industry, making their analysis essential (Njowa, 2017).

The mining industry has at times been found to deliver poor returns relative to other industries and destroy shareholder value. Hall (2003) linked this destruction of shareholder value to the estimation and declaration of Mineral Reserves which include unprofitable tonnes or ounces. This is because the declaration of the maximum quantity of Mineral Reserves is often perceived to be desirable by the markets and has a positive effect on the share prices of mining companies. Mining companies have, at times, also been found to destroy shareholder value by taking investment decisions based on overly optimistic commodity price outlooks, which then fail to be materialise, resulting in poor returns on investment and the destruction of value. Although it is a widely accepted fact that commodity prices are cyclical and are comprised of ‘boom’ and ‘bust’ periods, mining companies commonly invest in projects during ‘boom’ periods when commodity prices are increasing, with the expectation that the upward trend will continue. When the inevitable downward turn occurs, mining companies are often caught off guard. The commodity price sentiments of mining companies can often be derived from their Mineral Reserve declarations.

1.3 The South African mining industry

South Africa is a country that is well endowed with natural resources. The country possesses significant deposits of a variety of mineral resources which include precious and base metals, industrial minerals, coal and precious stones. Statistics compiled by Statistics South Africa show that although the country has a variety of mineral resources; coal, platinum group metals (PGM), gold and iron ore contributed

approximately 80% of the income earned from mining in 2015 (Statistics South Africa, 2017), as shown in Table 1.1.

Table 1.1: Income in the South African mining industry for 2012 and 2015

Type of mining	2012		2015	
	R million	% contribution	R million	% contribution
Mining of coal and lignite	96 097	24,4	117 958	28,1
Mining of gold and uranium ore	66 957	17,0	63 674	15,2
Mining of iron ore	68 061	17,3	60 699	14,5
Mining of chrome ore	11 412	2,9	16 383	3,9
Mining of manganese	10 254	2,6	17 093	4,1
Mining of platinum group metal ore	106 555	27,1	91 099	21,7
Dimension stone (granite, marble, slate and sandstone)	630	0,2	1 146	0,3
Limestone and limeworks	2 398	0,6	2 717	0,6
Other stone quarrying, including stone crushing and clay and sandpits	10 289	2,6	16 584	4,0
Mining of diamonds (including alluvial diamonds)	8 694	2,2	15 055	3,6
Other chemical and fertiliser mineral mining	3 330	0,8	5 976	1,4
Extraction and evaporation of salt	280	0,1	215	0,1
Other mining activities and service activities incidental to mining	7 822	2,0	10 295	2,5
Other minerals and materials n.e.c.	582	0,1	639	0,2
Total	**393 361**	**100,0**	**419 533**	**100,0**

Source: Statistics South Africa, (2017)

The reporting of Exploration Results, Mineral Resources and Mineral Reserves in South Africa is governed by the guidelines of the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code), which was first published in March 2000 and adopted by the Johannesburg Stock Exchange (JSE) later that year (SSC Committee, 2016). The SAMREC Code sets out the minimum reporting requirements for Mineral Resources and Mineral Reserves in South Africa.

This research study focussed on the long-term price assumptions and Mineral Reserve estimates of South African gold and platinum mining companies as they make up a significant portion of the country's earnings from mining, collectively making up approximately 37% of mining income in 2015, according to Statistics South Africa (2017). The other major South African commodities, coal and iron ore, were not included in this research study as they consist of many different product types and are traded in different markets; and are thus less comparable (for the purposes of this research study) than the more fungible gold and platinum commodities. This research study also focussed on the reporting of the South African gold and platinum mining companies from 2000, as this period can be

associated with better Mineral Resource and Mineral Reserve reporting, as a result of the introduction of the SAMREC Code in 2000.

This research study reviewed platinum and gold prices from 2000 to 2016 to assess how they compared with the long-term price assumptions of South African gold and platinum mining companies in this period. The research conducted also assessed the relationship between the long-term commodity price outlooks of South African gold and platinum mining companies and their Mineral Reserve estimates since 2000 (when the SAMREC code was first introduced). The analysis also aimed to determine whether there is a reasonable range within which South African gold and platinum mining companies should make their long-term commodity price assumptions. The scope of the research was limited to South African gold and platinum mining companies due to their significant collective contribution to the country's mining income and due to the more fungible nature of gold and platinum mining products.

1.4 A brief history of the gold mining industry in South Africa

Gold mining in South Africa began, in earnest, in the Witwatersrand Goldfields in 1886 (Virtual Metals Research and Consulting Limited, 2006). There is evidence of the occurrence of small-scale mining in the South African greenstone belts long before 1886, but little recorded information is available for periods prior to the 1830s (Virtual Metals Research and Consulting Limited, 2006). In 1836 gold mining took place in the greenstone belts of Northern Kwa-Zulu Natal and mines were developed in the Murchison, Giyani and Pietersburg greenstone belts (Virtual Metals Research and Consulting Limited, 2006). In 1875, in present day Krugersdorp, gold was discovered on the Kromdraai farm, which marked the beginning of mining in the Witwatersrand region. The Pioneer Reef in Barberton was discovered in 1883, followed by the discovery of the Witwatersrand Main Reef in 1886 (Virtual Metals Research and Consulting Limited, 2006).

The discovery of the rich gold deposits of the Witwatersrand Basin resulted in an influx of gold miners from across the world and the establishment of many new companies and South Africa's formal gold mining industry. Africa's largest stock

market, now the JSE Limited, was established in 1887 specifically to fund the mining industry (Virtual Metals Research and Consulting Limited, 2006). Seven companies dominated the early years, and most of the 20th century, of the South African gold mining industry (Table 1.2). But significant restructuring took place in the latter part of the 20th century and the early part of the 21st century, as illustrated in Table 1.3. This restructuring occurred due to increasing mining depths and operating costs in South African gold mines, decreasing output, weak gold prices in the mid-1980s and 1990s and increasing output from other countries (Virtual Metals Research and Consulting Limited, 2006).

Table 1.2: Companies established in the early years of the South African gold mining industry

Company/event	Established
Union Corporation	1886
Gold Fields of South Africa	1887
Johannesburg Consolidated Investment Company Ltd (JCI)	1889
Rand Mines	1893
General Mining and Finance Corporation	1895
Anglo American	1917
Anglo-Transvaal Consolidated Investment Company (Anglovaal)	1934

Source: Virtual Metals Research and Consulting Limited, (2006)

Table 1.3: Major South African gold mining industry restructuring events

Date	Restructuring Event
1992	Rand Mines is unbundled when its mining interests are separated out as Randgold & Exploration (Randgold).
1994	Randgold becomes a single commodity gold mining house with a portfolio of marginal gold mines.
1995	Johannesburg Consolidated Investments is divided into a non-mining group, (Johnnies Industrial Corp), a gold, ferrochrome and base metals group, (JCI Ltd) and a PGM producer (Anglo Platinum). JCI's primary remaining gold asset was a 50% stake in Western Areas, in partnership with Placer Dome Inc.
1995	Western Areas (established in 1959) merges with South Deep in 1995.
1997	Randgold is rationalised into three South African mining companies; Durban Roodepoort Deep (now DRDGOLD), Harmony Gold Mining and Crown Consolidated Recoveries and an offshore gold company, Randgold Resources, operating the Syama mine in Mali. DRDGOLD Limited is later expanded as a result of the acquisition of a number of mines from other operating companies.
1998	AngloGold Limited is formed through a merger of the gold operations, mineral rights and exploration activities of Anglo American Corporation and the subsequent acquisition of a number of non-South African mining assets.
1998	Placer Dome Inc takes a 50% stake in South Deep, which it holds in partnership with JCI Gold.
Early 2000s	Harmony acquires Elandsrand and Deelkraal mines from the then AngloGold and, together with ARMgold, the then only BEE gold company listed on the JSE, acquired Freegold from AngloGold. Subsequently, Harmony merges with ARMgold.
2003	African Rainbow Minerals (formerly a major shareholder in ARMgold, and now in Harmony) merges with Avmin and Harmony acquires Avgold.
2004	AngloGold Ashanti Ltd, South Africa's largest gold producer, is formed through the merger of AngloGold Limited and Ashanti Goldfields of Ghana.

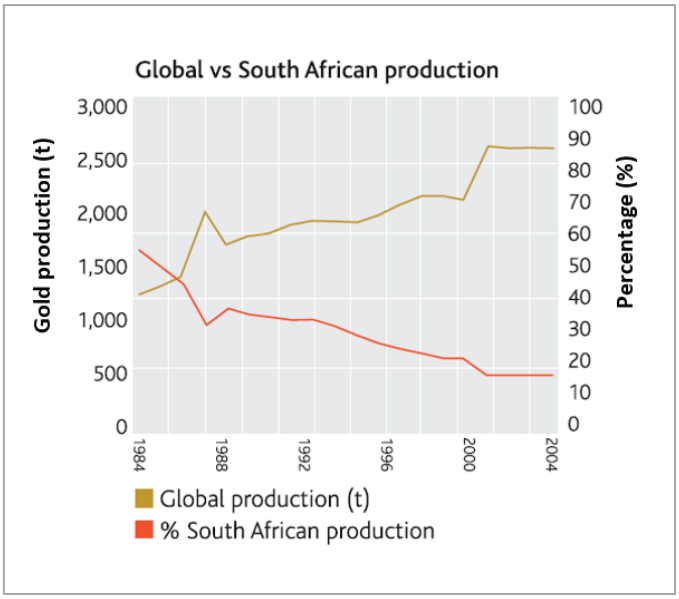
Source: Virtual Metals Research and Consulting Limited, (2006)

In the 120-year period from 1884 to 2004, about 50,055t of gold was produced from South African gold mines, accounting for 33% of all gold produced over that period. In 2006 it was estimated that South Africa's total remaining gold resources amounted to approximately 40,000t, with 8,000t to 10,000t being economically recoverable depending on the Rand-denominated gold price and cost scenarios (Virtual Metals Research and Consulting Limited, 2006). South Africa dominated global gold production throughout the 20th century, with peak production reaching 1,000t (about 67% of global supply) in 1970. However, the South African gold mining industry is now considered mature and possibly in decline, with gold output decreasing to 342t in 2004, with 91% (321t) of the 2004 production coming from five publicly listed companies, namely; AngloGold Ashanti, Gold Fields, Harmony, DRDGOLD and Western Areas (Virtual Metals Research and Consulting Limited, 2006). South Africa's declining contribution to global gold production is illustrated in Table 1.4 and Figure 1.1. In 2016, South Africa was the seventh largest gold producer in the world, behind China, Australia, Russia, the United States, Canada and Peru, as shown in Table 1.5 (U.S. Geological Survey, 2017).

Table 1.4: Gold physical accounts for South Africa, 1980–2009 (tonnes)

Year	Opening stock	Production (extraction)	Discoveries	Other volume changes	Closing stock (sub-soil assets)	Total volume sold	Net changes in inventories	Closing stock (including inventories)	Years to depletion
	Tons								
1980	21 117	675	-	-	20 442	675	0	20 442	30
1981	20 442	658	-	-	19 784	661	-3	19 781	30
1982	19 784	664	-	-	19 120	662	2	19 122	29
1983	19 120	680	-	-	18 440	669	11	18 451	27
1984	18 440	682	-	-	17 758	685	-3	17 755	26
1985	17 758	673	-	-	17 085	677	-4	17 081	25
1986	17 085	640	-	-	16 445	642	-2	16 443	26
1987	16 445	604	-	-	15 841	602	2	15 843	26
1988	15 841	620	-	-	15 221	618	2	15 223	25
1989	15 221	608	-	-	14 613	606	2	14 615	24
1990	14 613	605	-	-	14 008	596	9	14 017	23
1991	14 008	601	-	-	13 407	601	0	13 407	22
1992	13 407	613	-	-	12 794	613	0	12 794	21
1993	12 794	619	-	-	12 175	619	0	12 175	20
1994	12 175	580	-	-	11 595	580	0	11 595	20
1995	11 595	524	-	-	11 071	524	0	11 071	21
1996	11 071	498	-	-	10 573	496	2	10 575	21
1997	10 573	491	-	-	10 082	508	-17	10 065	21
1998	10 082	465	-	-	9 617	465	0	9 617	21
1999	9 617	451	-	-	9 166	455	-4	9 162	20
2000	9 166	431	-	-	8 735	406	25	8 760	20
2001	8 735	395	-	-	8 340	387	8	8 348	21
2002	8 340	399	-	-	7 941	396	3	7 944	20
2003	7 941	373	-	-	7 568	376	-3	7 565	20
2004	7 568	337	-	-	7 231	347	-10	7 221	21
2005	7 231	295	-	-	6 936	270	25	6 961	24
2006	6 936	272	-	-	6 664	283	-11	6 653	25
2007	6 664	253	-	-	6 411	243	10	6 421	25
2008	6 411	213	-	-	6 198	199	14	6 212	29
2009	6 198	198	-	-	6 000	187	11	6 011	30

Source: Statistics South Africa, (2012)



Source: Virtual Metals Research and Consulting Limited, (2006)

Figure 1.1: South African gold production relative to global supply

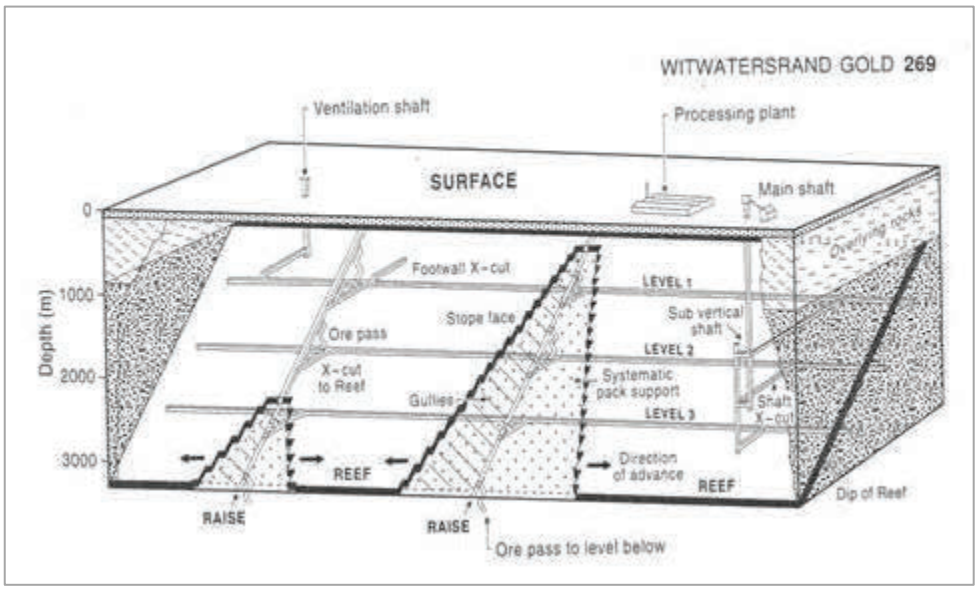
Table 1.5: World gold production and reserves (tonnes)

	Mine production		Reserves[8]
	2015	2016[e]	
United States	214	209	3,000
Australia	278	270	9,500
Brazil	81	80	2,400
Canada	153	170	2,400
China	450	455	2,000
Ghana	88	90	990
Indonesia	97	100	3,000
Mexico	135	125	1,400
Papua New Guinea	60	65	1,500
Peru	145	150	2,400
Russia	252	250	8,000
South Africa	145	140	6,000
Uzbekistan	102	100	1,700
Other countries	897	900	13,000
World total (rounded)	3,100	3,100	57,000

Source: U.S. Geological Survey, (2017)

Mining operations in the Witwatersrand Goldfields mostly employ the conventional breast mining method. This mining method involves the mining of the narrow and moderate dip gold reefs at narrow mining widths and with a high labour intensity. Breast mining involves developing footwall excavations from underground shafts towards the reef horizon. Raise developments are then excavated on reef dip to expose the reef horizon. Advance strike gullies (ASGs) are then developed at an angle to the reef raises along the strike of the gold reef. The panels from which the bulk of the gold ore is extracted are then excavated in between the ASGs, with the

panels being mined sequentially in a Christmas-tree like pattern. Gold ore is liberated from the host rock by drilling holes into the reef with pneumatic rockdrills, and loading the drill holes with explosives for fragmentation. Mechanical scrapers are used to transfer the broken ore from the panel face into the ASGs, then into footwall ore passes for tramming (transporting) along the footwall developments into main ore passes and ultimately up the underground shafts to surface processing facilities. Support for on-reef excavations is commonly by a combination of hydraulic props and timber packs (Viljoen, 2009). A typical layout of the breast mining method for the Witwatersrand Basin gold mines is shown in Figure 1.2.



Source: Viljoen, (2009)

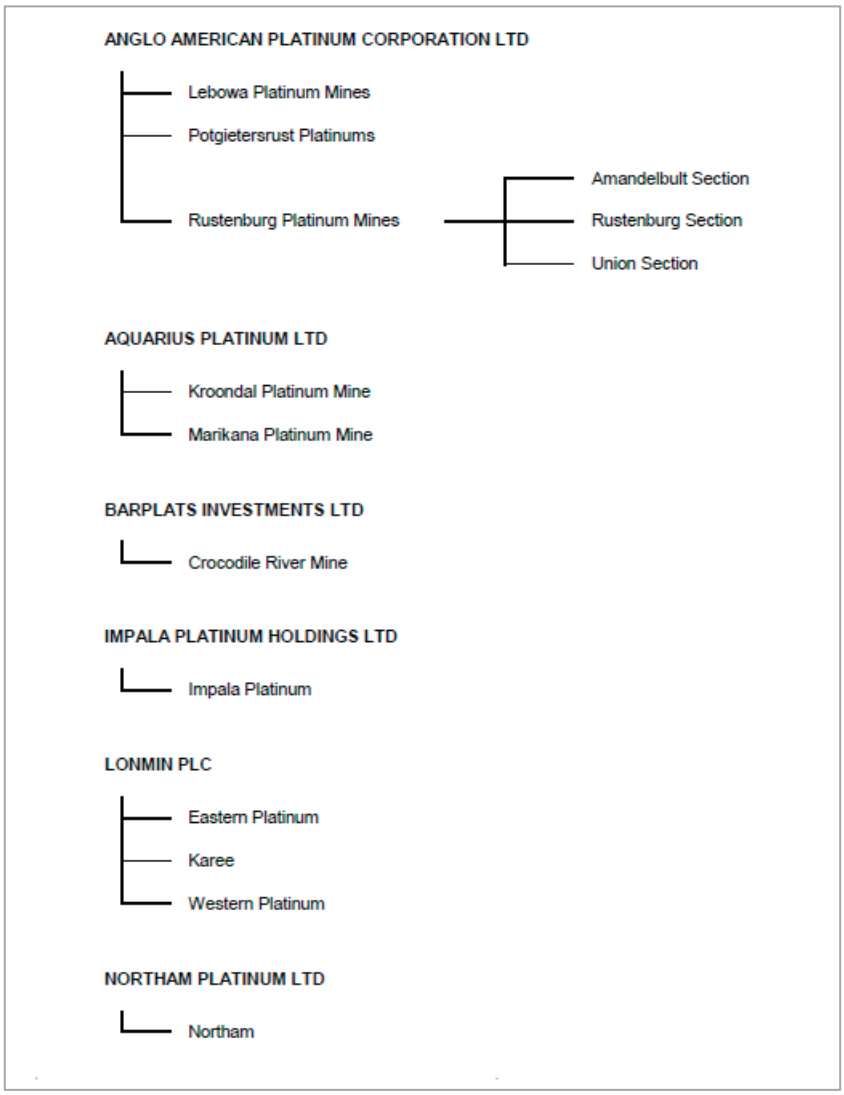
Figure 1.2: Mining method used for extracting narrow reefs in the Witwatersrand Basin

1.5 A brief history of the platinum mining industry in South Africa

South Africa's platinum group metal (PGMs) are mostly sourced from the Bushveld Complex. The platinum deposits of the Bushveld Complex were first encountered by Adolf Erasmus near Naboomspruit and were initially exploited on a limited scale from 1924 to 1926 (Hochreiter, *et al.*, 1985). The first platinum mine in South Africa was operated by the Transvaal Platinum Limited in 1924, but was forced to close down in December 1926 due to the patchy nature of the mineralisation (Department of Minerals and Energy, 2003).

In 1924, Dr Hans Merensky discovered a gently dipping layered platiniferous reef on the Maandagshoek farm near the Lydenburg district (Hochreiter, *et al.*, 1985). This reef was found to be quite extensive, unlike the previously discovered sporadic reefs, and came to be known as the Merensky Reef. In 1929, the Meresnky Reef had been traced for 150km and 200km on the eastern and western limbs of the Bushveld Complex, respectively, and had been identified as the largest platinum deposit in the world (Hochreiter, *et al.*, 1985). As far back as 1908, it had been discovered that certain chromitite layers in the Bushveld Complex contained sporadic platinum values. However, it was only after the discovery of the Merensky Reef that the Upper Group 2 (UG2) chromitite layer was discovered and found to have persistent PGM grades of between 3.5g/t and 29g/t. The UG2 reef was found to be between 20m and 370m below the Merensky Reef (Hochreiter, *et al.*, 1985).

In the early years of the South African platinum mining industry, various small companies were founded to exploit the newly discovered platinum deposits. These included Premier Rustenburg Platinum Limited, Eerstegeluk Platinum Mines Limited and the Rustenburg Platinum Limited. These companies were taken over by Johannesburg Consolidated Investment Co Limited (J.C.I.) in 1926 (Hochreiter, *et al.*, 1985). In 1929, a J.C.I.-administered company, Potgietersrust Platinum Ltd started platinum production from the Merensky Reef. In 1985, three large-scale mining companies were producing platinum from the Bushveld Complex, namely J.C.I.'s Rustenburg Platinum Mines Limited, Gencor's Impala Platinum Limited and Lonrho's Western Platinum Limited (Hochreiter, *et al*., 1985). In December 2003, the Department of Minerals and Energy described the South African PGM industry as consisting of 6 major platinum mining companies as illustrated in Figure 1.3.



Source: Department of Minerals and Energy, (2003)

Figure 1.3: South African platinum group metal mining companies as at December 2003

South Africa's production of PGMs has been steadily increasing for most of the 20th century, and the early parts of the 21st century, with production decreases only occurring post the 2008 Global Financial Crisis (Table 1.6). In 2016, South Africa had the highest platinum production and was second to Russia in terms of palladium production, but remained the country with the highest PGM reserves as shown in Table 1.7.

Table 1.6: PGM physical accounts for South Africa, 1980–2009 (tonnes)

Year	Opening stock	Production (extraction)	Discoveries	Other volume changes	Closing stock (sub-soil assets)	Total volume sold	Net changes in inventories	Closing stock (including inventories)	Years to depletion
	Tons								
1980	75 610	114	-	-	75 496	112	2	75 498	662
1981	75 496	116	-	-	75 380	104	12	75 392	650
1982	75 380	85	-	-	75 295	98	-13	75 282	886
1983	75 295	90	-	-	75 205	104	-14	75 191	836
1984	75 205	107	-	-	75 098	113	-6	75 092	702
1985	75 098	122	-	-	74 976	118	4	74 980	615
1986	74 976	121	-	-	74 855	120	1	74 856	619
1987	74 855	128	-	-	74 727	130	-2	74 725	584
1988	74 727	132	-	-	74 595	131	1	74 596	565
1989	74 595	134	-	-	74 461	137	-3	74 458	556
1990	74 461	142	-	-	74 319	136	6	74 325	523
1991	74 319	143	-	-	74 176	141	2	74 178	519
1992	74 176	153	-	-	74 023	137	16	74 039	484
1993	74 023	176	-	-	73 847	154	22	73 869	420
1994	73 847	184	-	-	73 663	162	22	73 685	400
1995	73 663	183	-	-	73 480	175	8	73 488	402
1996	73 480	189	-	-	73 291	184	5	73 296	388
1997	73 291	197	-	-	73 094	187	10	73 104	371
1998	73 094	200	-	-	72 894	194	6	72 900	364
1999	72 894	216	-	-	72 678	199	17	72 695	336
2000	72 678	207	-	-	72 471	199	8	72 479	350
2001	72 471	230	-	-	72 241	193	37	72 278	314
2002	72 241	237	-	-	72 004	208	29	72 033	304
2003	72 004	265	-	-	71 739	241	24	71 763	271
2004	71 739	276	-	-	71 463	260	16	71 479	259
2005	71 463	303	-	-	71 160	259	44	71 204	235
2006	71 160	309	-	-	70 851	266	43	70 894	229
2007	70 851	304	-	-	70 547	258	46	70 593	232
2008	70 547	276	-	-	70 271	223	53	70 324	255
2009	70 271	271	-	-	70 000	251	20	70 020	258

Source: Statistics South Africa, (2012)

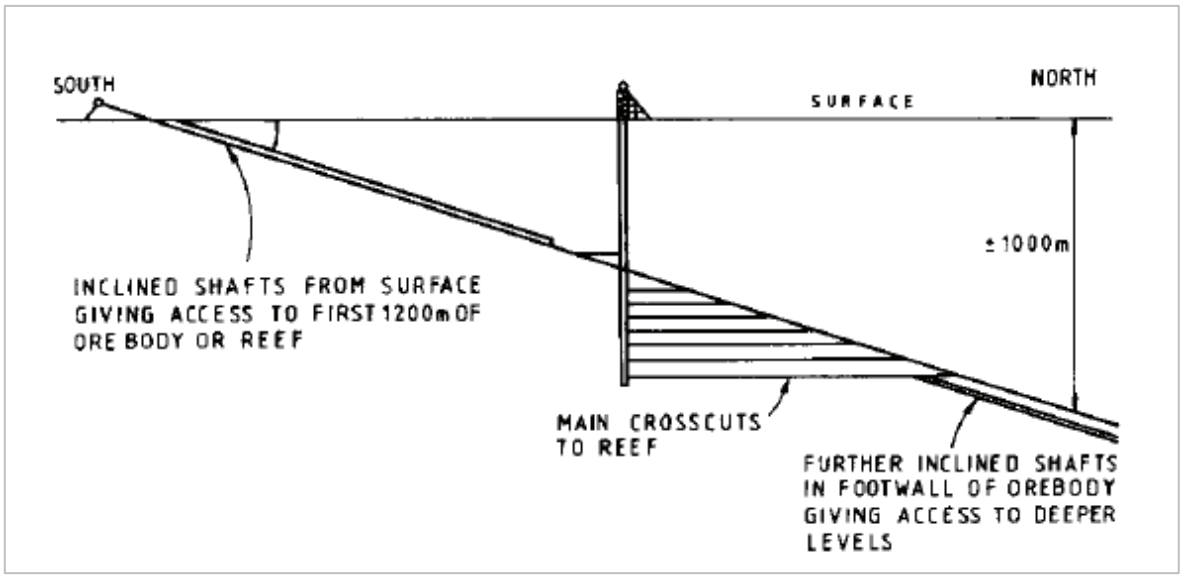
Table 1.7: World platinum and palladium production and reserves (kilograms)

	Mine production				PGMs Reserves[7]
	Platinum		Palladium		
	2015	2016[e]	2015	2016[e]	
United States	3,670	3,900	12,500	13,200	900,000
Canada	7,600	9,000	21,000	23,000	310,000
Russia	22,000	23,000	81,000	82,000	1,100,000
South Africa	139,000	120,000	83,000	73,000	63,000,000
Zimbabwe	12,600	13,000	10,000	10,000	1,200,000
Other countries	4,000	3,400	8,300	6,600	NA
World total (rounded)	189,000	172,000	216,000	208,000	67,000,000

Source: U.S. Geological Survey, (2017)

South African platinum mines often employ mining methods similar to the narrow reef breast mining methods of the South African gold mines. As the South African platinum mining industry is considerably younger than the gold mining industry, it exploits a greater proportion of shallower deposits, with some platinum operations exploiting reef outcrops. Where the platinum-bearing reefs of the Bushveld Complex outcrop to surface, incline shafts are developed either on or below the reef to exploit the first 1,200m (approximately) of reef. Vertical shafts are then sunk to exploit the deeper Mineral Reserves, which are beyond the economic limit of mining from the

incline shaft. Footwall development is then undertaken towards the reef horizon, to expose the orebody. Inclined shafts can also be developed, as part of life extensions, to access ore beyond the reach of the vertical shaft. South African platinum mines mostly use scattered breast mining, as well as longwall and up-dip mining methods, which are variations of scattered breast mining (Hochreiter, *et al.*, 1985). Figure 1.4 shows a section through a typical platinum mine, with an illustration of the typical main development.



Source: Hochreiter, *et al*.,(1985)

Figure 1.4: Section showing the main development of a typical platinum mine

1.6 A brief history of the international Mineral Resource and Mineral Reserve reporting codes and reporting scandals

The history of Mineral Resource reporting comes from the reporting of governments and international organisations on inventories of strategic energy minerals such as coal, oil, gas and uranium. Governments usually established and reported on mineral inventories for strategic planning purposes, with international organisations sourcing mineral inventory reports from governments to establish global inventories of these strategic minerals. An example of such an international organisation is the International Atomic Energy Agency (IAEA), which in the 1970s developed a resource reporting and classification system for global uranium inventories (Camisani-Calzolari, 2004). The requirement for a global uranium inventory was necessitated by the development of nuclear weapons in the 1940's and the

commercialisation of nuclear power plants in the 1970's (Camisani-Calzolari, 2004). The IAEA resource classification system reported uranium resources in terms of contained metric tonnes of uranium, with a classification of the resources based on exploitation costs and confidence in the uranium metal quantities reported in the estimates. Governments were required to maintain good records of mineral inventories to allow reporting into international organisations such as IAEA, which is the reason why the United Nations (UN) Framework Classification was established. The UN Framework Classification was a code generated for reporting into governments, as opposed to the market, for the purpose of maintaining national mineral inventories (Camisani-Calzolari, 2004).

With the rise of the capital markets and international finance in the late 20th century and the globalisation of mining, the focus of Mineral Resource reporting shifted away from governments to investors. The major difference in the two forms of reporting was in the quality and depth of the reported information. Governments are interested in the *in-situ* estimates of mineral deposits for their mineral inventories, while the market is interested in the portion of the orebody that can be exploited economically, within the given technical and economic assumptions. The need for international mineral reporting codes focussed on Mineral Resource reporting for investors was made evident by the reporting scandals that occurred in the global mining industry in the late 20th century. The two major reporting scandals which promoted and accelerated the development of investor-focussed international mineral reporting codes in the mining industry were the Poseidon nickel boom in Australia and the Bre-X gold scandal in Indonesia (Camisani-Calzolari, 2004).

The Poseidon nickel boom was a stock market bubble that started due to the nickel shortages of the 1960s, which were caused by increased demand as a result of the Vietnam War and industrial action at the major Canadian producer, Inco. The shortages resulted in the nickel price skyrocketing to £7 000 per ton (Simon, 2003). Poseidon NL (no liability), mining exploration company, had made a major nickel discovery at Windarra in Western Australia in 1969 (Simon, 2003). Poseidon's share price started rising quickly when drilling results from Windarra became known to some insiders and when the company started making announcements on the drilling results. The share price rose from AUD0.80 in early September to AUD12.30 on 1

October 1969 (Simon, 2003). Although the Poseidon share price rally could be explained by company fundamentals, the share prices of other mining companies also started to climb, as people started taking speculative positions in nickel stock; with the Australian Stock Exchange (ASX). All mining index rising 44 percent from October to December 1969. When Poseidon issued an update on the drilling results at Windarra on 9 November 1969, the share price was trading at AUD50 (Simon, 2003). In the pandemonium caused by the Poseidon stock, investors fell victim to speculative companies such as Tasminex NL (Tasminex), which was another mining exploration company. In January 1970, a Tasminex director had panned some drill samples and identified some heavy metals at Mount Venn in Western Australia, which then sparked rumours of a nickel discovery. The rumours led to the Tasminex share price increasing from AUD2.80 to AUD16.80, and then eventually to AUD96 after the publication of an interview with the company chairman (Simon, 2003). The company chairman later sold his shares at a significant profit and the share price ultimately plummeted as no nickel discovery was made at Mount Venn. The ASX All Mining Index peaked in January 1970, while the Poseidon share price peaked in February 1970, followed by a sudden and substantial decline of both the mining index and the Poseidon share price; as nickel prices also began to plummet (Simon, 2003).

The Bre-X scandal occurred between 1994 and 1997 when Bre-X Minerals Ltd appeared to have discovered a massive gold deposit near the Busang River in Borneo, Indonesia. Bre-X had acquired the Busang property in 1993 and began initial exploration drilling in 1994, with some promising results (Mining.com, 2016). However, in 1994 the project manager and geologist, Michael de Guzman, began salting the samples with gold filings from his wedding ring. Guzman then started buying gold panned from locals for the salting of samples. For over two-and-a half years Guzman bought CAD61k of gold for his salting campaign (Mining.com, 2016). Results from Busang sent the market into a frenzy as it was announced that the deposit contained 200 million ounces of gold. This saw the Bre-X share price skyrocket from the CAD0.30 price of the initial private offerings to more than CAD250 on the open market (Mining.com, 2016). In 1997, when Freeport McMoRan acquired a 15% stake in the Busang project, it conducted a due diligence of the drilling by twining holes that were already drilled. It discovered that the deposit only

contained minor traces of gold. As the news around Freeport McMoRan's discovery of sample salting made its way to the market, Guzman mysteriously jumped to his death from a helicopter and the Bre-X share price crashed (Mining.com, 2016).

The Poseidon nickel boom resulted in the Australian government and regulators pressuring the mining industry to develop proper reporting standards. In response the Australian mining industry then constituted the Joint Ore Reserves Committee (JORC) which published the first version of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code) in 1989 (Camisani-Calzolari, 2004). The publication of the JORC Code was followed by the SAMREC Code (South Africa), National Instrument 43–101 (Canada), The Reporting Code (England) and the SME Guide (USA); which are at least 90% compatible with the JORC Code (Camisani-Calzolari, 2004). In the case of South Africa, the SAMREC Code has been incorporated into Section 12 of the JSE Listing Requirements for mining companies, which means that mining companies listed on the JSE have to declare and publish their Mineral Resources and Mineral Reserves in line with the guidelines of the SAMREC Code (Business Report, 2006). The reporting scandals highlighted the importance of ensuring that mining companies undertake sound Mineral Resource and Mineral Reserve reporting, so that investors are protected from misleading or fraudulent reporting.

1.7 Research hypothesis

In the context of the historical reporting scandals, this research report assessed the quality of Mineral Reserve reporting in the South African gold and platinum industries. The hypothesis this research study aimed to assess related to whether in fact *"Mineral Reserve estimates are most sensitive to long-term commodity price assumptions, relative to the other modifying factors"*. The research study also aimed to determine whether South African platinum mining companies have consistently assumed realistic long-term commodity prices, relative to spot prices, when compared to South African gold mining companies for most of the period from 2000 to 2016; and whether this suggests that South African gold mining companies had a relatively higher quality of Mineral Reserve reporting in this period.

1.8 Research objectives

The international mineral reporting codes and scandals indicate the overarching need for improved confidence in the reporting of Mineral Resources and Mineral Reserves. Hence the objectives of this research study were to:

- Assess the quality of the Mineral Reserve reporting of South African gold and platinum companies from 2000 to 2016;
- Assess how the long-term commodity price assumptions used in the Mineral Reserve estimates of gold and platinum mining companies compared with actuals from 2000 to 2016;
- Evaluate the relationship between the long-term commodity price assumptions of South African gold and platinum mining companies and their Mineral Reserve estimates from 2000 to 2016; and
- Determine whether there is a reasonable range within which South African gold and platinum mining companies should set their long-term commodity price assumptions, to improve confidence in the reporting of Mineral Reserves.

1.9 Report structure

This thesis is divided into five chapters, followed by references. A brief description of each chapter is given in the next section.

Chapter 1 is the introductory chapter and gives the background of the research topic, with a discussion on the history and significance of South Africa's gold and platinum mining industry. Chapter 1 also includes a discussion of some of the major mining industry reporting scandals that led to the development of the international mineral reporting codes.

Chapter 2 contains a literature review that focuses on the development and guiding principles of the international mineral reporting codes. A discussion of the processes involved in estimating Mineral Reserves in accordance with the international mineral reporting codes is also included in this chapter. The importance of long-term

commodity prices in the Mineral Reserve estimation process is also discussed in Chapter 2. An assessment of some of the practices of South African gold and platinum mining companies when determining their long-term commodity prices concludes the chapter.

Chapter 3 provides details on the methodologies employed in conducting the research study. It includes the sources of information used and the kind of analysis applied.

Chapter 4 is the results chapter, providing an analysis of the quality of the Mineral Reserve reporting undertaken by South Africa's gold and platinum mining companies from 2000 to 2016. Chapter 4 also includes an analysis of the relationships between the Mineral Reserve estimates of the gold and platinum mining companies and their relevant modifying factors, including long-term commodity prices, by assessing the correlations between these parameters. Chapter 4 concludes with an assessment of possible ranges for the determination of long-term commodity prices by analysing the relationship with impairments recorded by the gold and platinum mining companies in the period under review. The major findings included in Chapter 4 include: the improved Mineral Reserve reporting of South Africa's gold and platinum mining companies since the introduction of the SAMREC Code, the statistical confirmation of Mineral Reserves being most sensitive to long-term commodity prices relative to the other modifying factors and the limitation of impairments through the selection of an appropriate long-term commodity price range relative to spot commodity prices.

Chapter 5 presents the conclusions that can be derived from the research. The chapter also provides future areas of research that were not covered by this research study.

2 LITERATURE REVIEW

2.1 Chapter overview

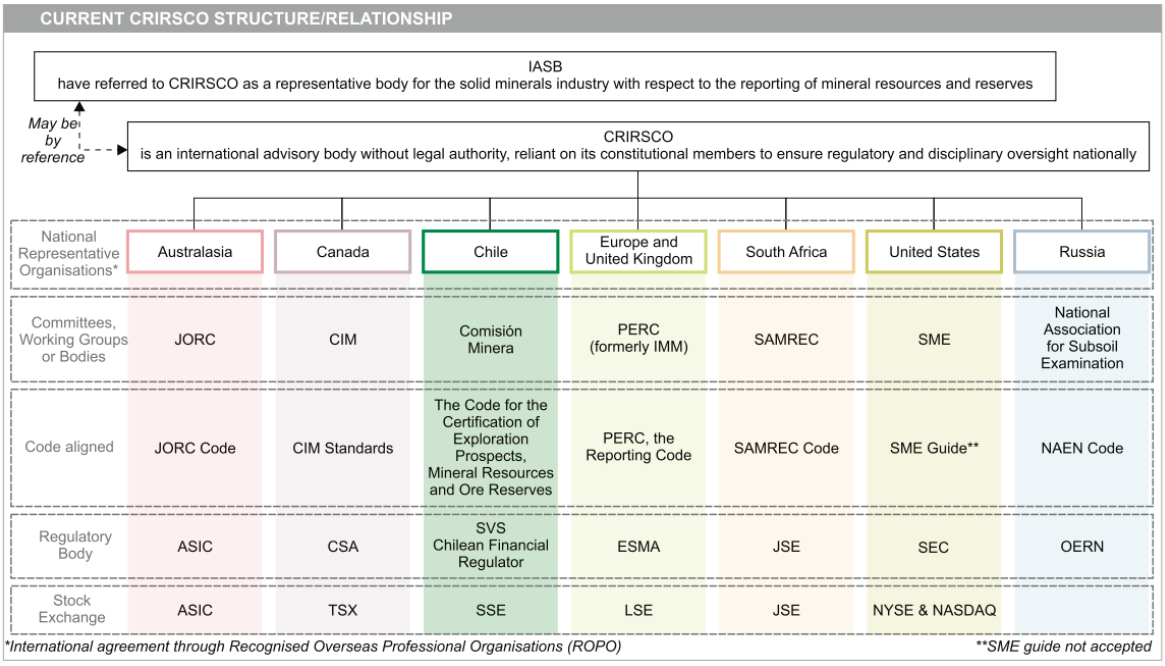
This chapter discusses the various international mineral reporting codes, which are relevant to the declaration of Mineral Resources and Mineral Reserves. The discussion then extends to the best practice methodologies for the declaration of Mineral Reserves, in line with the international mineral reporting codes. The major inputs and considerations when estimating Mineral Reserves, those of pay-limits and commodity prices, and the discounted cash flow (DCF) methodology which is often used to determine the economic viability of Mineral Reserves, are also discussed. A discussion of the theory behind commodity price movements over time, in the form of the Prebisch-Singer hypothesis and mean-reversion theory, are discussed. Finally, some of the practices of South African gold and platinum companies, when it comes to Mineral Reserve declarations, are introduced.

2.2 Mineral Resource and Mineral Reserve reporting under the international mineral reporting codes

The process of estimating and declaring Mineral Resources and Mineral Reserves is an important aspect of the functions of mining companies. These estimates support the raising of project finance, form the basis of capital depreciation calculations and inform the terms and pricing for transactions. Investors in listed mining companies also use declared Mineral Resources and Mineral Reserves to inform their investment decisions regarding these companies. To guide the estimation and declaration process there are a number of international mineral reporting codes which set out the minimum standards, recommendations and guidelines for the public reporting of Mineral Resources and Mineral Reserves. These international mineral reporting codes include the SAMREC Code, the JORC Code and the National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) of Canada (Noppé, 2014).

The Committee for Mineral Reserves International Reporting Standards (CRIRSCO), formerly known as the Mineral Definitions Working Group, was formed following the hosting of 15th Council of Mining and Metallurgical Institutes (CMMI) Congress in Sun City, South Africa, in 1994; with the aim of harmonising the mineral

reporting definitions, which were later agreed through the Denver Accord in 1997. The national reporting organisations (NROs) represented at the CMMI congress included those of Australia, Canada, South Africa, the United States of America, the United Kingdom, Ireland and Western Europe (Njowa et al., 2014). CRIRSCO published a template in 2006, later updated in 2013, which harmonises the definitions, classification, estimation processes and the public reporting of Exploration Results, Mineral Resources and Mineral Reserves. The CRIRSCO template provides a guideline for any country wishing to align its reporting code to international standards, while also taking account of country specific issues (Njowa et al., 2014). The SAMREC, JORC and NI 43-101 Codes are some of the many international mineral reporting codes which are aligned to the CRIRSCO template as shown in Figure 2.1.

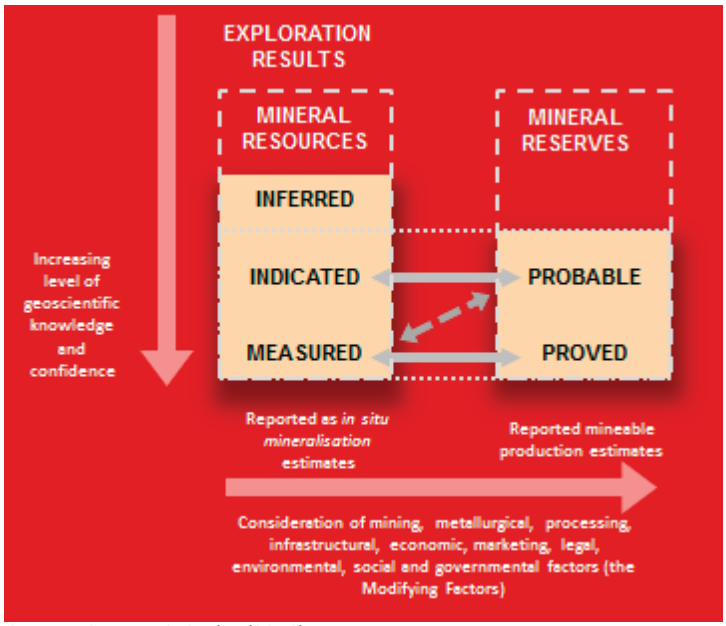


Source: Njowa et al. (2014)

Figure 2.1: Relationship CRIRSCO and the international mineral reporting codes

In accordance with the international mineral reporting codes, Mineral Resources are the part of the mineral deposit which demonstrate prospects for *'eventual economic extraction'*, while Mineral Reserves are considered to be the part of a mineral deposit whose extraction is both technically feasible and economically viable at the time of computation. Mineral Reserves are derived from the Measured and Indicated

portions of Mineral Resources and the international mineral reporting codes indicate that they should be derived from a minimum of a pre-feasibility study (PFS) for pre-production projects and mine plans and production schedules for operational projects (Noppé, 2014). Several modifying factors are applied to Mineral Resources to derive Mineral Reserves and Figure 2.2 illustrates how the conversion process is conducted in accordance with the 2016 version of the SAMREC Code (SSC Committee, 2016). The importance of Mineral Reserve estimation was highlighted by Njowa (2017, pp.161), when he stated that the "*extraction and processing of Mineral Reserves is the only major source of the revenue generated by a mining company. Hence the Mineral Reserves are the most important economic asset for a mining company. Its financial strength depends largely on the scale and quality of its Mineral Reserves. Resources and reserves are also the source of future cash inflows from sale of minerals and they provide the basis for acquiring funds through borrowings and additional equity financing*".



Source: SAMREC Code, (2016)

Figure 2.2: Relationship between Exploration Results, Mineral Resources and Mineral Reserves

The international mineral reporting codes indicate that the grouping of Mineral Reserves into the Proved and Probable Reserve categories is reliant on confidence in the modifying factors. Proved Reserves reflect high confidence in the modifying factors and Probable Reserves indicate reduced confidence in the modifying factors.

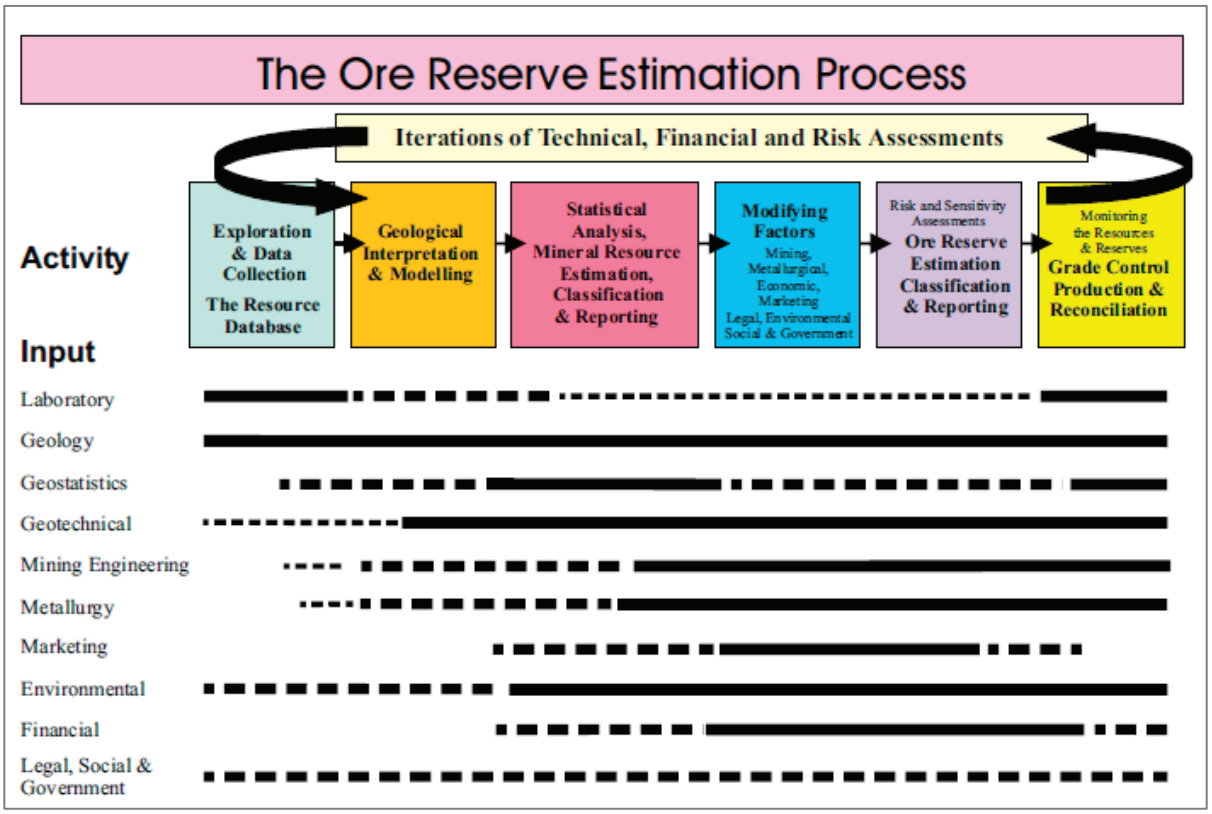
The international mineral reporting codes also allow for the re-evaluation of Mineral Reserves, which can lead to their reclassification as Mineral Resources or complete removal from the Mineral Resources, if they are found to no longer be technically and economically viable for extraction. Such reclassification should not be based on short-term commodity movements or demand constraints but on long-term changes to the underlying modifying factors (Noppé, 2014). There have been cases in recent years where mines have been closed or placed on care and maintenance despite Mineral Reserves having been reported for these mines immediately before the ceasing of operations. Such practices are not in line with the intentions of the international mineral reporting codes for Mineral Reserves to be reported on the basis of technically and economically viable mine plans (Njowa, 2017).

2.3 The Mineral Reserve estimation process

The Mineral (or Ore) Reserve process is an iterative process which begins with the exploration and data collection phase. This is then followed by geological interpretation and modelling; to allow for the estimation of a Mineral Resource. It is this Mineral Resource which forms the basis of the Mineral Reserve estimate. Other non-resource inputs (modifying factors) are used in the conversion of a Mineral Resource to a Mineral Reserve. Once mining operations commence, Mineral Reserve estimates are managed and modified through grade control and reconciliation processes (Appleyard, 2001). The iterative Ore (or Mineral) Reserve estimation process is shown in Figure 2.3.

The modifying factors used in the Mineral Reserve estimation process include mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors (as shown in Figure 2.3), all of which are fundamental to the Mineral Reserve estimation process. The thick solid lines in Figure 2.3 indicate the areas where each of the activities and modifying factors are most applicable in the Mineral Reserve estimation process, while the thick dotted line indicate where the activities and factors are less applicable. The thinner dotted lines indicate limited applicability of the activities and modifying factors in the respective steps in the Mineral Reserve estimations process, and the blank areas indicate non-applicability. Each of these modifying factors consists of several components which require due

consideration in the estimation of Mineral Reserves. Table 2.1 shows some of the components of these modifying factors.



Source: Appleyard, (2001)

Figure 2.3: The Ore Reserve estimation process

Table 2.1: Typical modifying factor components

Modifying Factors	Typical Components
Mining	Mining method; dilution and mining recovery; operating and capital costs; the degree of selective mining; grade control; geotechnical influences; ventilation; the use of stope fill; the mode of access to underground mines and the overall mining sequence.
Metallurgical	Test sample representivity; product specification; metallurgical recovery and throughput; operating and capital costs, the analysis of variable ore characteristics and their potential impact on process performance and overall economics.
Economic	Commodity price forecasts (including the impact of hedging), royalties, operating and capital costs.
Marketing	Sales projections, analysis of demand trends and estimates for off-site treatment terms and costs, product quality and blending abilities (for commodities such as iron ore, coal and industrial minerals).
Legal	Political risk and security of tenure, and environmental factors.

Source: Appleyard and Smith (2001)

2.4 The importance of commodity price assumptions to the Mineral Reserve estimation process

Appleyard and Smith (2001, p.327) stated that *"cost and revenue estimation and other feasibility study outcomes are included in the economic analysis which contributes to the final Ore Reserve estimation"*. Appleyard (2001, p.8) stated that *"the right Ore Reserve is the one that best achieves its owner's objectives. Normally the main objective is to maximise the economic return, which may be measured by the Internal Rate of Return or by the Net Present Value at a selected discount rate or by some other technique"*. Appleyard (2001, p.8) also stated that *"the most sensitive inputs to a mine valuation are those which relate to revenue. While metallurgical recovery directly relates to revenue, the factors which are usually subject to most variation are the price for the commodity"*. These statements indicate that although all other modifying factors are important in the estimation of Mineral Reserves, commodity price assumptions are often among the most important of the modifying factors.

It should be noted that commodity prices are often quite volatile, and the international mineral reporting codes do not provide guidance on how often Mineral Reserve estimates are to be revised based on short-term commodity price movements. However, Appleyard and Smith (2001, p.327) indicated that "*failure to recognise that a price decrease means that a previous Ore Reserve is now a body of uneconomic mineralisation, can cause a company to continue operating until it is in a position where it can fail*". Baker and Giacomo (2001, p.669) stated that "*fundamental to the determination of reserves (and to a lesser extent resources) is the underlying metal price assumptions used in the estimation. Contained metal can be highly sensitive to metal price assumptions employed, especially where the margin between cost and revenue is small. At best a company could consider providing sensitivities of tonnes and grade to commodity price assumptions. At the very least we are of the view that companies should disclose the price at which the determinations are made (in appropriate currencies)".* Since long-term commodity price assumptions are highly important and sensitive input parameters in the Mineral Reserve estimation process, their relationship with Mineral Reserve declarations is worth studying. It was therefore important for this research study to explore the impact that commodity price estimates have on declared Mineral Reserves. The

other modifying factors were also evaluated as part of this research study, but specific focus was placed on long-term commodity price assumptions.

2.5 Commodity price assumptions for Mineral Reserve versus Mineral Resource reporting

Since the introduction of the SAMREC Code and its incorporation into Section 12 of the JSE Listing Requirements in 2000, South African listed mining companies have had to report their Mineral Resources and Mineral Reserves in accordance with the SAMREC Code (Business Report, 2006). The SAMREC Code provides minimum standards, recommendations and guidelines for the reporting of Mineral Resources and Mineral Reserves. The SAMREC Code is applicable to all styles of solid mineralisation, which excludes commodities such as oil, gas and water. The SAMREC Code is aimed at ensuring that investors, potential investors and their advisers are provided with sufficient information when assessing South African mining investments, so as to make informed decisions (SSC Committee, 2016). However, due to the varied nature of mineralisation encountered in the South African mining environment, the code is essentially principle-based in its requirements, leaving considerable amounts of discretion to Competent Persons (CPs) when making their estimation and disclosures. The SAMREC Code is based on the principles of materiality, transparency and competency. Materiality speaks to the need to public reporting of Mineral Resources and Mineral Reserves to include all relevant disclosures that investors and their advisors would expect to make a reasonable assessment of the estimates. Transparency relates to the reporting of sufficient information in a clear and unambiguous manner, while competency relates to the requirement for sufficiently qualified and experience persons to take responsibility for the estimation of Mineral Resources and Mineral Reserves (SSC Committee, 2016). With regards to the disclosing of the long-term commodity prices used in Mineral Reserve estimation, Njowa (2017, pp. 144) noted that "*all the CRIRSCO-type codes require some form of statement on how the commodity prices have been derived, but SAMREC is the only one to mandate the use of historical full cycle price averages. In general, other reporting codes do not require the actual prices to be reported publicly, but they do require an explanation of the method by which they have been derived*".

The reporting of Mineral Resources and Mineral Reserve in accordance to SAMREC Code differs principally on the basis that Mineral Resources are required to demonstrate *"reasonable prospects for eventual economic"*, while Mineral Reserves are considered to be the *"economically mineable part of a Measured and/or Indicated Mineral Resource"* (SSC Committee, 2016). This means that while Mineral Resources can be reported on the basis that they "*might become economically extractable"*, Mineral Reserves need to be demonstrate economic feasibility under prevailing conditions (SSC Committee, 2016). Therefore while Mineral Resources may be reported at a commodity price which may be realised at some indefinite future date, Mineral Reserves should ideally be reported at a price that closely tracks historical and prevailing prices. This is why this research study specifically focused on long-term commodity price assumptions relating to Mineral Reserves and how they relate to spot prices.

2.6 Pay limits and cut-off grades

One of the most important steps in estimating a Mineral Reserve involves the determination of the pay limit or reserve cut-off grade. Storrar (1981, p.145) defined the pay limit of ore as *"the minimum value at which it can be mined and treated without profit or loss, i.e. when revenue obtained from the specific mineral product balances expenditure incurred in mining and treating the ore, and, possibly, also transporting the marketable product to the delivery point*".

The parameters of the pay limit are (Storrar, 1981):

- Revenue from the sales of the mineral product;
- Working costs;
- Extraction/recovery;
- Mine call factor (MCF);
- Waste sorting;
- Development, reclamation and other ore sources; and
- Tonnage discrepancy: shortfall or excess.

The pay limit determines the lowest grade that is allowable for a block of ore to be included in the Mineral Reserve. However, this should not just be a simple exercise

of including all the blocks that are above the pay limit in the Mineral Reserve, as it is important that every block of ore that is mined, can be mined at a profit. The pay limit and Mineral Reserves of a mine should be reviewed on an annual or bi-annual basis, to account for the changes in the value of the ore mined, the mining rate, working costs or any of the other parameters, which might have occurred between estimation intervals (Storrar, 1981).

2.7 Discounted cash flow (DCF) modelling

Once the mineable ore blocks have been selected using the pay limit, these ore blocks are usually scheduled to form a mine plan, economic viability is then assessed using a DCF model. The DCF model involves the forecasting of project cash flows based on the production volumes and qualities contained in the mine plan. Commodity price and exchange rate assumptions, operating and capital cost estimates and royalty and tax estimates are also inputs in the DCF model. The future cash flows are then discounted using a risk-adjusted discount rate; to arrive at a net present value (NPV) for the project. It is when the NPV of the project is positive that the project is considered economically viable and the declaration of a Mineral Reserve can be justified in accordance with the guidelines of international mineral reporting codes such as the SAMREC code (Birch, 2016). The DCF model and the subsequently derived NPV is considerably sensitive to the input parameters used in the economic assessment. NPV is sensitive to technical parameters such as the production profile, estimated grade, processing recoveries and operating cost assumptions. In addition, commodity price assumptions are often the most sensitive input in the process of determining NPV and by extension the Mineral Reserve estimate. It is for this reason that this research study aimed to closely assess the impact of the commodity price assumptions used on Mineral Reserve estimates.

The international mineral reporting codes are mostly not prescriptive on how long-term commodity price assumptions for Mineral Reserve estimates should be determined. The international mineral reporting codes are principle-based codes which allow considerable discretion by the Competent/Qualified Person (CP/QP) in estimating and reporting on Mineral Resources and Mineral Reserves, provided that their approaches and methodologies are reasonable and defendable. The

international mineral reporting codes mostly require that the method used in deriving the Mineral Reserve commodity price be disclosed, unless there are competitive reasons to withhold such disclosure. A guideline on commodity prices assumptions from the 2016 SAMREC Code (p.25) stated that: *"Commodity prices and exchange rates used for Mineral Reserve estimation should be disclosed. For commodities traded on metal exchanges, reasonable forward-looking prices should be used. Such prices should be based on historic price averages and should be disclosed. However, for commodities not traded on metal exchanges, it is recognised that disclosure of a specific price may put a company at a competitive disadvantage, and this should be stated*" (SSC Committee, 2016). While the international mineral reporting codes were put in place to protect investors from mining scandals such as the Bre-X and the Noble Minerals scandals which occurred in the 1990's, these codes were not designed to be prescriptive. This is due to the considerable number of minerals (some of which have unique characteristics) included in the scope of their standards and guidelines (Camisani-Calzolari, 2004). Due to the discretion given to the CP/QP, Mineral Reserve estimates can be demonstrated to be compliant with the international mineral reporting codes, while possibly still not being 'technically and economically viable' in reality. An example of such a practice is when Mineral Reserves are declared for operations that are on care and maintenance. Operations that are placed on care and maintenance are often uneconomic under prevailing conditions, therefore the Mineral Reserves for these operations may fail to meet the economic viability criteria for Mineral Reserve declaration if the long-term commodity prices used in the estimation align with prevailing prices. The discretion given to CPs/QPs is often not a concern when it comes to the technical viability of declared Mineral Reserves, as they are often technical experts and rely on other technical experts in conducting Mineral Reserve estimates. The concern is often with the economic viability of the Mineral Reserves, which is often heavily dependent on commodity price and exchange rate assumptions, which no expert can claim to be able to forecast with certainty.

2.8 Commodity price movements over time

The exercise of forecasting long-term commodity prices is a challenging one due to the volatility that is associated with the market forces that determine commodity

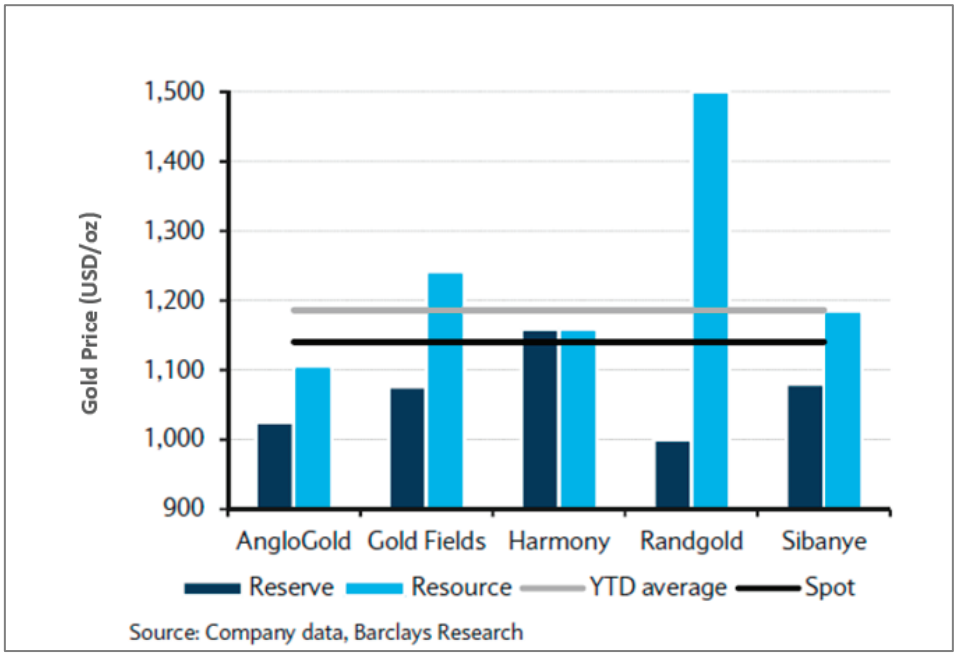
prices. These include supply and demand dynamics, technological developments and world economic growth trends. The volatility of commodity prices was well demonstrated by the commodities boom which was experienced in the lead-up to the 2008 Global Financial Crisis, the subsequent crash in the prices of commodities and the low-price environment that followed. There are many theories that have been developed to try and explain commodity price movements. One such theory is the Prebisch-Singer hypothesis, which states that real commodity prices should decrease over time due to the low income elasticity of demand for commodities and the larger productivity increases of manufacturing goods relative to primary commodities (Cashin and McDermott, 2001). Another theory used to explain real commodity price movements is based on the assumption that commodity prices oscillate around a mean value, which is referred to as mean-reversion (Hall and Nicholls, 2007). Cashin and McDermott (2001) demonstrated that there was evidence to support the Prebisch-Singer hypothesis by assessing real commodity prices over a 140-year period (1862-1999). They found that real commodity prices had on average shown a decline of 1.3 percent per year during this period. However they also found that there were periods of significant volatility within this period, with commodity prices moving by as much as 50% in a single year. Cashin and McDermott (2001) concluded that due to the persistently large and unpredictable movements in prices, variability makes forecasting future commodity prices challenging. The analysis of historical real commodity prices also demonstrated that commodity prices undergo cycles of slumps and booms. In the 140-year period assessed, it was found that there had been 18 complete cycles (consisting of both a boom and a slump) in industrial commodity prices, and that on average price slumps (4.2 years) last longer than average price booms (3.6 years) (Cashin and McDermott, 2001).

Day et al. (2000) stated that while the task of forecasting commodity prices is challenging, it is a task which mining companies cannot avoid. This is because views on long-term commodity prices inform investment decisions related to the development of new projects, the expansion or contraction of production and other strategic and operational decisions. The traditional methodology of forecasting commodity prices has often involved assessing historic prices, along with supply and demand dynamics and then projecting the data into the future in line with views

on economic growth trends. However trends in the late 20th century and the 21st century have shown deficiencies in the traditional forecasting methodology. This has been due to the effects of factors such as the substitution of some commodities in industrial processes and the growth of the secondary markets due to technological improvements in the recycling of some commodities; all of which have an impact on commodity prices (Day et al., 2000). For example, in 1997, 59% of lead production was from scrap and the use of lead in some products had been reduced or discontinued; with petrol being the most notable example, this resulted in a downward trend in the real long-term price of lead between 1986 and 1998 (Day et al., 2000). Downward trends were also observed in the long-term real prices for tin, copper, zinc and coal in last four decades of the 20th century (1960-1988). The real long-term gold price remained relatively flat over the period (Day et al., 2000). Statistics from the World Platinum Investment Council (2018), show that the effect of recycling on the supply of platinum has been steadily increasing since the beginning of the twentieth century. Recycling accounted for 9% of platinum supply in 2000, followed by a steady climb in the contribution of recycling to platinum supply in the first decade of the 21st century, with the contribution of recycling peaking at 39% of platinum supply in 2014. The contribution of recycling to platinum supply was 31% in 2016 and 2017 (World Platinum Investment Council, 2018). Day et al. (2000) stated that they expected a continuation in the downward trend of real long-term commodity prices in the 21st century, as observed in the last 40 years of the 20th century. Although there would still be price cycles with peaks and troughs in commodity prices, Day et al. (2000) expected the downward trend in commodity prices to continue due to technological developments and changes in the supply dynamics of key commodities. Day et al. (2000) also predicted that there would be a boom in commodity prices in the early years of the 21st century as prices were depressed at the end of the 20th century, they stated that this price boom would be fuelled by improvements in the Asian economies. However, this price boom would be followed by the continued real decline in commodity prices. The trends in commodity prices from 2000 to present day appear to generally adhere to the theories presented by Day et al. (2000).

2.9 South African gold and platinum company practices and performance

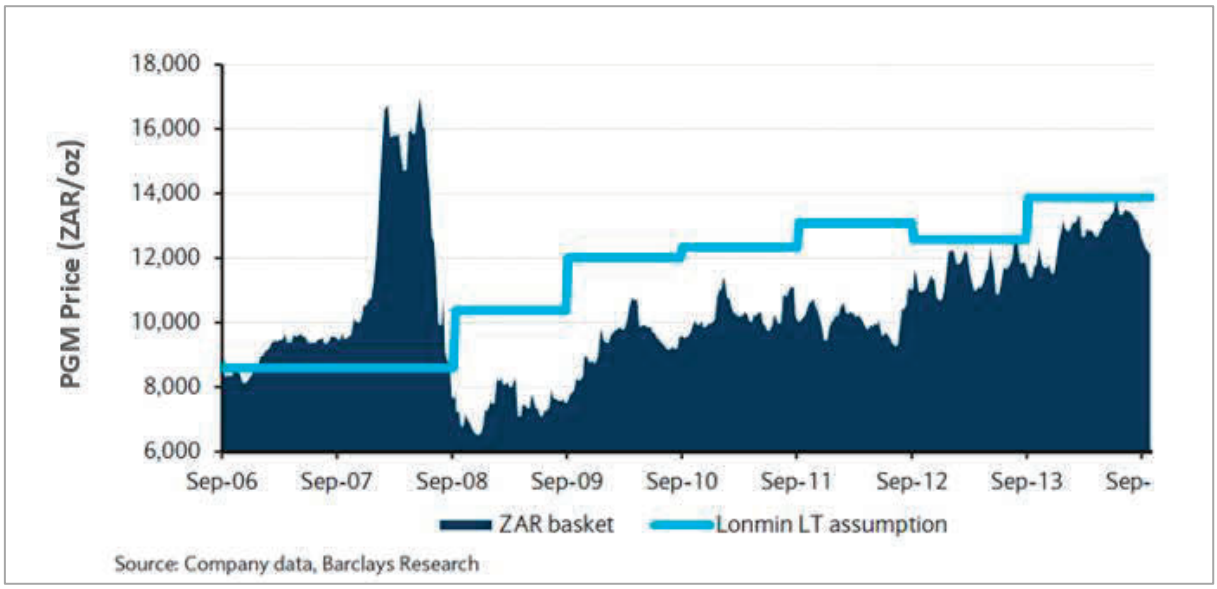
This research study aimed to assess the long-term commodity price assumptions, relative to actual prices, of South African gold and platinum mining companies between 2000 and 2016; and how these assumptions influenced Mineral Reserve declarations. An analysis conducted by Barclays Bank PLC (2015) showed that 65% of the South African platinum industry was cash flow negative at 2015 spot prices, compared to only 22% of the South African gold industry. Although the better performance of the gold miners can probably be attributed to the better performance of the gold price relative to the platinum price around 2015, the quality of investment and operational decisions of the two sectors (based on their commodity price assumptions) could possibly have contributed to the vast differences in their financial performance. Figure 2.4 shows that South African gold mining companies adopted conservative long-term price assumptions for their Mineral Reserve estimations relative to the 2015 gold spot price, with only Harmony Gold assuming a higher price than spot (Barclays Bank PLC, 2015). These conservative assumptions probably informed the operational and investment decisions of the South African gold miners, which may have contributed to their better cash flow positions.



Source: Barclays Bank PLC, (2015)

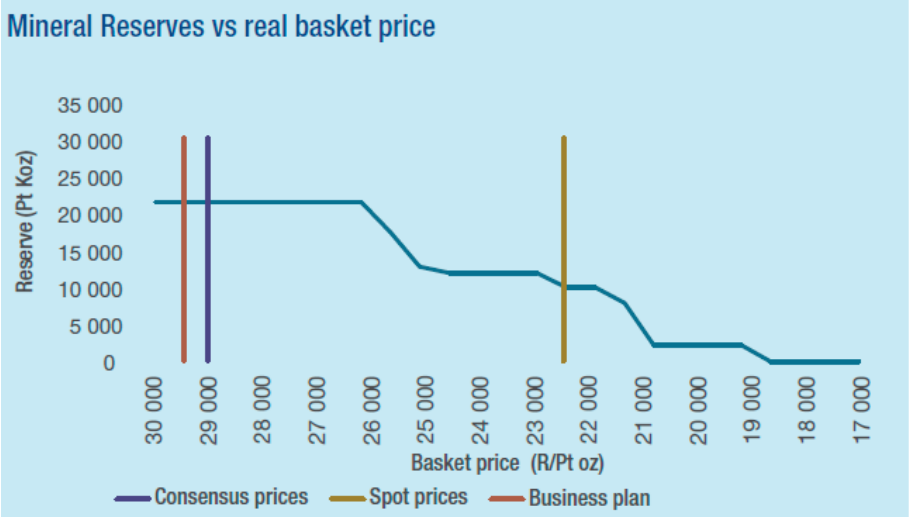
Figure 2.4: South African gold mining company Mineral Resource and Mineral Reserve price assumptions relative to spot prices

Figure 2.5 and Figure 2.6 show the ZAR PGM basket price assumptions of Lonmin Plc (Lonmin) and Impala Platinum Holdings Limited (Impala), respectively, relative to the prevailing spot prices between 2006 and 2016. The PGM basket price is an equivalent price for the basket of PGMs based on the relative grades or prill splits for the major metals of PGM ore. Figure 2.5 shows that for the period 2008 to 2014, Lonmin consistently assumed a long-term basket price which was considerably higher than the spot prices. Among the poor investment choices made by Lonmin, probably as a result of its optimistic long-term price outlook, was the decision to bring the K4 shaft into production in 2011, on the assumption of an improving global economy and by extension PGM pricing. The decision involved increasing headcount by 4314 employees and spending significant amounts of capital on development. However, continually weak PGM prices rendered the introduction of K4 unnecessary and financially unviable, which led to it being placed on care and maintenance in November 2012 (Barclays Bank PLC, 2014). Figure 2.6 indicates that had Impala adopted a long-term ZAR PGM price closer to spot prices in 2016, its Mineral Reserves would have halved, although the long-term PGM price assumed by Impala was only 30% above spot prices (Impala, 2016). This shows the significant effect of long-term commodity price assumptions on Impala's Mineral Reserve estimates.



Source: Barclays Bank PLC, (2014)

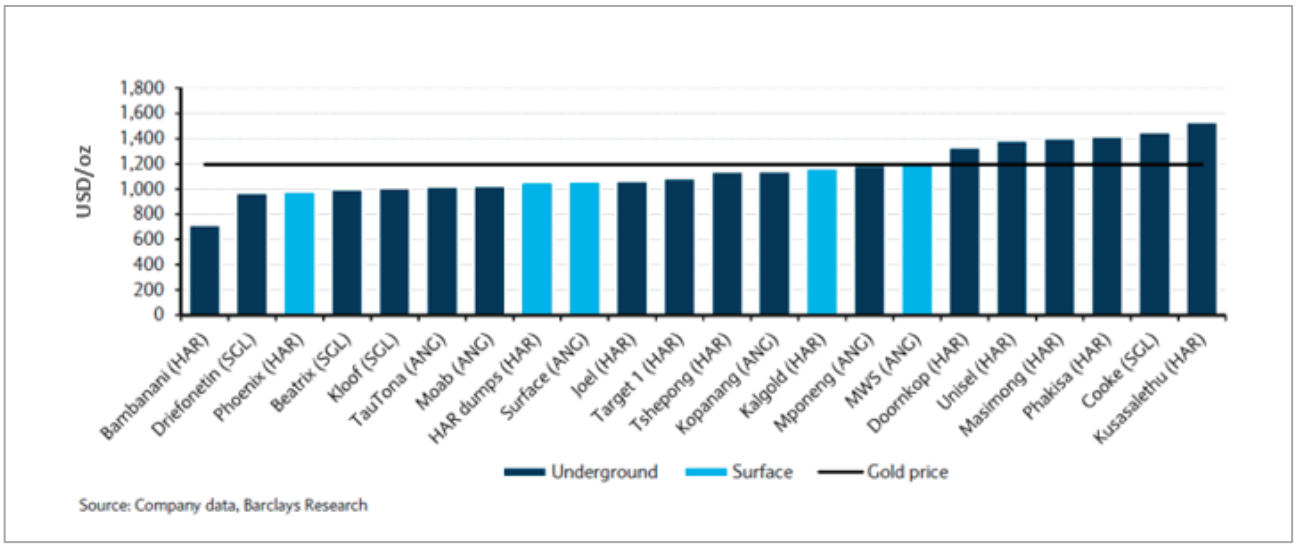
Figure 2.5: ZAR PGM basket compared to Lonmin PLC long-term real price assumptions (2006-2014)



Source: Implats, (2016)

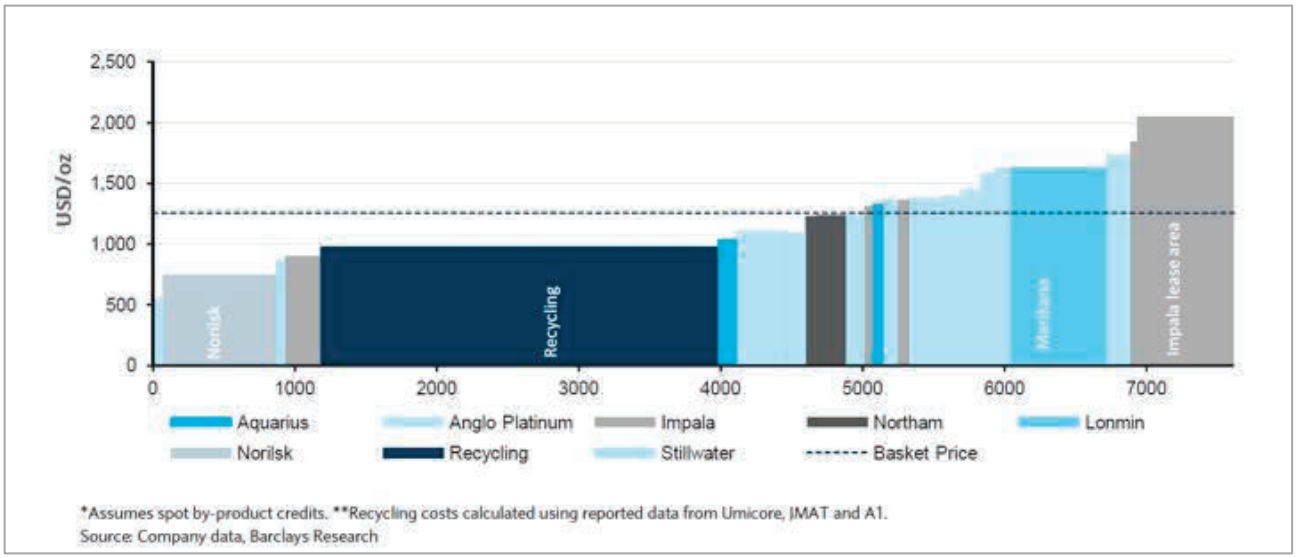
Figure 2.6: Impala Platinum Mineral Reserve 2016 ZAR PGM basket prices compared long-term real price assumptions and consensus prices

Figure 2.7 shows the 2015 South African gold production cost curve, which shows that South African gold mines were mostly cash flow positive in 2015 (Barclays Bank PLC, 2015). The global platinum cost curve shown in Figure 2.8 indicates that South African platinum mines were mostly cash flow negative in 2014 (Barclays Bank PLC, 2014). It is mostly Harmony Gold's (indicated as 'HAR' in Figure 2.7) operations which were in the upper quartile of the gold cost curve and were loss-making in 2015. Figure 2.7 also shows that Harmony Gold had the most optimistic long-term price assumption amongst the South African gold miners in 2015. This suggests that there is a relationship between financial performance and long-term commodity price assumptions. It should however be stated that Harmony Gold operates mines which have some of the lowest grades in the South African gold mining sector, which may also be a factor for its fourth quartile position on the cost curve.



Source: Barclays Bank PLC, (2015)

Figure 2.7: South African gold production cost curve (2015)



Source: Barclays Bank PLC, (2014)

Figure 2.8: Global platinum cost curve including capex (2014)

3 RESEARCH METHODOLOGY

This research study followed the methodology as outlined below:

- Reviewed the annual reports and other publications (available in the public domain) of major South African gold and platinum mining companies to establish their long-term commodity price assumptions from 2000 to 2016;
- Analysed the quality of the Mineral Reserve declarations of the major South African gold and platinum mining companies from 2000 to 2016;
- Compared the long-term commodity price assumptions of the major South African gold and platinum mining companies to actual prices and broker forecasts from 2000 to 2016;
- Determined the correlations between the long-term commodity price assumptions and the other modifying factors to the Mineral Reserve declarations of the major South African gold and platinum mining companies from 2000 to 2016;
- Evaluated a reasonable range for the long-term commodity price assumptions for the Mineral Reserve estimations of South African gold and platinum mining companies; and
- Made conclusions and recommendations based on the analysis.

4 THE MINERAL RESERVE DECLARATIONS OF SOUTH AFRICAN GOLD AND PLATINUM MINING COMPANIES

4.1 Chapter overview

This chapter begins with an assessment of the quality of Mineral Reserve reporting by South Africa's gold and platinum mining companies since the introduction of the SAMREC Code in 2000, up to 2016. The assessment focuses on the granularity and detail of Mineral Reserve reporting, with a focus on the reporting of long-term commodity prices and other modifying factors. The chapter then assesses the impact of long-term commodity prices and the other modifying factors on the Mineral Reserves, by evaluating the correlations between these parameters and the Mineral Reserve estimates. The chapter concludes by deriving a reasonable range, relative to spot prices, for long-term commodity prices, based on an analysis of the non-financial asset impairments recorded by South Africa's gold and platinum mining companies in the period under review.

4.2 The quality of Mineral Reserve reporting by South African gold and platinum mining companies

Due to the non-prescriptive nature of the SAMREC Code, there has historically been variation in the quality of Mineral Reserve reporting which has been stated to be in compliance with the SAMREC Code. This is as a result of Competent Persons exercising the discretion that the SAMREC Code affords them. Although the SAMREC Code provides minimum standards and guidelines for the public reporting of Mineral Resources and Mineral Reserves, Competent Persons could exercise some discretion in terms of which elements to report on. In his review of the compliance of Public Reports with the guidelines of the SAMREC Code, Rupprecht (2016) discovered that common non-compliance issues included the non-disclosure of assumed commodity prices and other economic assumptions. The 2016 Edition of the SAMREC Code has gone some way in addressing the previously unbound reporting discretion exercised by Competent Persons by introducing the *'if not, why not*' basis of reporting, which requires that Competent Persons report on every aspect specified in Table 1 of the SAMREC Code, or otherwise provide reasonable justification for not reporting on certain elements (SSC Committee, 2016). This reporting basis should go some way in addressing some of the omissions that have

been previously witnessed in the reporting of Mineral Resources and Mineral Reserves using the SAMREC Code.

There has been an upward trend in the quality of Mineral Reserve reporting by South African gold and platinum mining companies since the introduction of the SAMREC Code. At the time of the publication of the first edition of the SAMREC Code, in 2000, there was little to no reporting of the modifying factors used in estimating Mineral Reserves, but reporting improved progressively in the first decade of the new millennium, to the current situation where key modifying factors are generally reported in public reports. However, South African platinum mining companies still generally lag behind gold mining companies in terms of the granularity and comprehensives of their Mineral Reserves reporting. Major South African gold mining companies often have dual listings on the JSE and the New York Stock Exchange (NYSE) and this has generally resulted in a higher quality of reporting by these companies as they have to comply with the JSE Listing Requirements and the regulations of the Securities Exchange Commission (SEC), which regulates NYSE listed entities. The quality of Mineral Reserve reporting by South African gold and platinum mining companies from 2000 through to 2016 is discussed in the next sections.

4.2.1 South African gold mining company Mineral Reserve reporting quality

A progressive improvement in the Mineral Reserve reporting quality of South African gold mining is noticeable from 2000 to 2016. Anglo Gold Ashanti (AGA) can be considered to be the South African gold mining company that has had the most comprehensive Mineral Reserve reporting in the period under review. AGA has operations in South Africa, the Democratic Republic of Congo (DRC), Ghana, Guinea, Tanzania, South America and Australia. In 2016 the operations in South Africa made up 50% of AGA's entire Mineral Reserve base (Anglo Gold Ashanti, 2016). Table 4.1 shows the total Mineral Reserves reported for AGA's operations during the period, while Table 4.2 to Table 4.9 show the Mineral Reserves for AGA's South African operations over the period. Table 4.1 shows that while in 2000 AGA did not disclose the gold price used in estimating its Mineral Reserves (NR means

'not reported' in the tables below), this changed in 2001 and the company has consistently disclosed the Mineral Reserve long-term gold price since 2001.

Table 4.1: AGA: Total AGA Mineral Reserves 2000 - 2016

ANGLO GOLD ASHANTI						
AGA Total Mineral Reserves						
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Gold Price (USD/oz)	Gold Price (ZAR/kg)
2016	5.00	45.00	50.00	1.34	1 100	530 000
2015	5.24	46.45	51.69	1.39	1 100	431 000
2014	10.35	47.12	57.47	1.32	1 100	398 452
2013	14.68	53.26	67.94	1.43	1 100	360 252
2012	16.34	57.74	74.08	1.43	1 300	290 064
2011	16.71	58.89	75.60	1.77	1 100	269 841
2010	16.34	54.86	71.20	2.54	850	238 028
2009	14.58	56.87	71.45	2.75	800	227 627
2008	20.78	54.11	74.89	2.24	720	200 698
2007	21.20	51.90	73.10	2.33	600	148 536
2006	14.70	52.20	66.90	2.41	550	114 939
2005	14.90	48.40	63.30	2.70	400	86 807
2004	16.20	62.70	78.90	2.99	375	94 764
2003	14.10	49.00	63.10	2.88	350	78 769
2002	17.00	55.30	72.30	3.12	325	94 041
2001	17.50	50.83	68.33	3.12	275	71 262
2000	22.02	65.61	87.63	3.58	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

AGA's Kopanang mine is a deep level underground mine which has been in operation since 1984, and is located in the Free State province of South Africa, some 10km south-east of the town of Orkney. Kopanang exploits the Crystalkop Reef (CR) and Vaal Reef (VR) of the Witwatersrand Basin, to a depth of 2,334m via a single shaft system, using the sequential grid mining layout (Anglo Gold Ashanti, 2016). The Mineral Reserves of Kopanang, as a conventional narrow reef gold mine, are driven by modifying factors (in addition to gold price) such as cut-off grade, stoping width, dilution, mine call factor (MCF) and metallurgical recoveries; all of which have been reported for the operation since 2002 as shown in Table 4.2. The stoping width cut-off has increased progressively over the period, while average dilution has decreased and MCF and recovery have remained relatively flat.

Table 4.2 AGA: Kopanang Mineral Reserves 2000-2016

Kopanang Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2016	0.30	0.19	0.49	5.44	9.52	105	55.7%	68.3%	95.6%
2015	0.35	0.40	0.75	6.64	9.52	105	53.5%	68.0%	95.3%
2014	0.35	0.90	1.25	6.02	9.46	106	54.8%	67.5%	94.3%
2013	0.45	1.00	1.45	6.67	9.43	106	51.5%	70.5%	95.5%
2012	0.22	1.17	1.39	7.35	11.54	104	55.3%	65.6%	96.4%
2011	0.40	2.40	2.80	6.47	4.81	104	52.2%	63.0%	96.5%
2010	0.31	2.80	3.11	6.62	4.81	104	50.9%	69.2%	95.6%
2009	0.22	3.13	3.35	5.71	4.90	102	54.0%	68.4%	97.5%
2008	0.33	3.67	4.00	7.69	4.90	102	22.6%	68.5%	97.8%
2007	1.44	2.90	4.34	7.09	6.86	102	51.0%	64.0%	98.0%
2006	0.43	4.41	4.84	8.35	5.88	102	49.0%	68.0%	98.0%
2005	0.40	5.20	5.60	8.22	6.96	102	49.0%	69.8%	97.7%
2004	0.70	5.30	6.00	7.22	8.82	102	64.0%	70.0%	97.9%
2003	0.80	4.60	5.40	7.15	9.31	102	66.0%	69.0%	96.9%
2002	1.00	5.00	6.00	8.03	9.00	100	70.0%	69.0%	96.2%
2001	0.57	5.05	5.62	7.29	12.28	NR	NR	NR	NR
2000	0.72	5.12	5.84	8.42	13.13	NR	NR	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

Moab Khotsong is the newest of the AGA operations, also near Orkney, having started production in 2003. Moab Khotsong exploits the VR orebody down to a depth of 3,052m using conventional scattered breast mining methods with backfill. In 2014 the neighbouring AGA mine, Great Noligwa, was merged with Moab Khotsong, with the Great Noligwa Mineral Reserves being reported as part of Moab Khotsong since then. Operations at Great Noligwa commenced in 1968 (Anglo Gold Ashanti, 2016). The Moab Khotsong Mineral Reserves have been reported along with the relevant conventional breast mining modifying factors since 2002 as shown in Table 4.3. The Great Noligwa Mineral Reserves and modifying factors were reported separately until 2013, as shown in Table 4.4.

Mponeng is the AGA operation which is also the deepest mine in the world, with mining operations taking place at a depth between 3,160m to 3,740m and development occurring at a depth of 3,841m below mine datum. Mining operations at Mponeng started in 1986 (Anglo Gold Ashanti, 2016). Underground access at Mponeng is through two hoisting shafts, a sub-shaft and two service shafts, with the sequential grid mining method being the main method of ore extraction. Mponeng mining operations target the Ventersdorp Contact Reef (VCR) and future operations are targeted at the Carbon Leader Reef (CLR), in the Witwatersrand Basin (Anglo Gold Ashanti, 2016). The cut-off grade, stoping width, dilution and MCF modifying factor thresholds for Mponeng have reduced progressively over the period under

review, while metallurgical recovery assumptions have remained relatively flat, as shown in Table 4.5.

Table 4.3: AGA: Moab Khotsong Mineral Reserves 2000- 2016

Moab Khotsong Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2016	0.73	4.26	4.99	9.31	4.84	146	41.2%	78.9%	96.1%
2015	0.67	4.60	5.27	9.69	5.07	148	46.8%	78.4%	96.1%
2014	0.80	4.68	5.48	10.06	5.16	166	45.8%	78.5%	95.9%
2013	0.45	5.67	6.12	10.00	3.70	137	53.0%	79.9%	96.0%
2012	0.57	6.04	6.61	10.02	3.55	145	51.9%	80.4%	96.0%
2011	0.45	6.55	7.00	10.62	5.01	142	49.6%	80.9%	96.5%
2010	0.62	6.87	7.49	12.47	5.00	142	26.8%	79.9%	95.3%
2009	0.39	6.75	7.14	11.14	5.49	138	34.8%	78.1%	97.0%
2008	0.61	6.71	7.32	10.86	4.83	145	49.3%	77.8%	96.9%
2007	0.29	6.97	7.26	10.16	5.08	148	57.0%	78.0%	97.0%
2006	0.06	3.11	3.17	11.79	6.61	151	38.0%	77.0%	98.0%
2005	0.20	3.40	3.60	12.25	7.84	151	46.0%	72.7%	97.6%
2004	0.00	9.00	9.00	14.09	3.73	134	35.0%	82.0%	97.8%
2003	0.00	8.40	8.40	13.93	4.10	122	40.0%	82.0%	97.7%
2002	0.00	9.00	9.00	13.45	8.46	160	30.0%	82.0%	96.0%
2001	0.00	4.66	4.66	14.30	NR	NR	NR	NR	NR
2000	0.00	9.71	9.71	16.36	NR	NR	NR	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

Table 4.4: AGA: Great Noligwa Mineral Reserves 2000-2013

Great Noligwa Mineral Reserves*									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2013	0.40	0.08	0.48	8.12	9.57	168	52.5%	58.0%	94.5%
2012	0.34	0.05	0.39	8.75	8.75	180	52.5%	59.4%	95.5%
2011	0.83	0.29	1.12	7.37	9.71	168	53.4%	59.0%	95.8%
2010	0.99	0.42	1.41	7.55	11.13	162	52.0%	63.2%	96.0%
2009	0.91	0.67	1.58	7.44	7.57	160	25.8%	63.2%	96.3%
2008	1.48	1.15	2.63	6.97	3.98	152	28.1%	66.9%	96.1%
2007	2.38	1.53	3.91	7.34	4.66	150	40.0%	67.0%	96.0%
2006	2.16	1.88	4.04	7.36	6.23	161	42.0%	68.0%	97.0%
2005	1.70	2.90	4.60	8.38	6.29	159	32.0%	68.7%	97.1%
2004	2.40	3.10	5.50	8.71	4.18	155	36.0%	72.0%	97.2%
2003	1.20	4.40	5.60	9.22	5.60	152	37.0%	70.0%	96.5%
2002	1.40	5.50	6.90	10.61	10.88	152	47.0%	76.0%	96.7%
2001	2.22	6.26	8.48	10.90	9.91	NR	NR	NR	NR
2000	1.95	7.42	9.37	11.47	10.95	NR	NR	NR	NR

* - Merged with Moab Khutsong in 2014

Source: Anglo Gold Ashanti (2000-2016)

Table 4.5: AGA: Mponeng Mineral Reserves 2000-2016

Mponeng Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2016	0.37	12.10	12.47	10.00	6.70	114	45.8%	81.0%	97.7%
2015	0.44	12.30	12.74	9.91	6.66	114	46.2%	80.9%	97.9%
2014	0.60	12.33	12.93	9.55	6.70	113	47.5%	81.0%	97.8%
2013	0.78	13.79	14.57	9.98	6.01	117	46.3%	81.2%	98.1%
2012	0.66	13.15	13.81	10.10	6.44	119	49.7%	83.8%	98.1%
2011	1.40	12.62	14.02	10.21	6.75	116	40.7%	83.7%	98.2%
2010	1.08	12.82	13.90	9.82	6.24	123	19.8%	82.0%	98.1%
2009	0.59	12.12	12.71	10.40	5.96	127	32.9%	84.4%	98.2%
2008	0.73	12.27	13.00	10.69	6.49	140	23.3%	85.3%	98.3%
2007	0.65	9.50	10.15	9.19	5.96	126	87.0%	85.0%	98.0%
2006	0.64	6.14	6.78	8.75	5.71	140	40.0%	89.0%	98.0%
2005	0.40	4.10	4.50	7.71	6.43	140	38.0%	89.0%	98.4%
2004	0.80	6.00	6.80	9.00	5.53	131	39.0%	96.0%	98.5%
2003	0.80	6.60	7.40	8.98	4.08	130	43.0%	97.0%	98.2%
2002	1.20	8.30	9.50	8.33	4.08	130	51.0%	97.0%	97.4%
2001	0.68	4.20	4.88	9.24	8.80	NR	NR	NR	NR
2000	1.75	8.51	10.26	9.07	9.80	NR	NR	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

Tau Tona is a deep level AGA gold mine, with operations reaching depths of 3,480m below mine datum. Located 70km south west of Johannesburg, near the town of Carletonville, Tau Tona began operating in 1961. The Tau Tona operations were merged with neighbouring Savuka mine in 2013 (Anglo Gold Ashanti, 2016). Initial mining was targeted at the VCR but current operations target the CLR. The mining method was changed from longwall mining to scattered grid mining. The Tau Tona Mineral Reserves have been estimated based on progressively declining stoping width cut-offs and MCFs over the period under review, however there have been significant improvements in the cut-off grade and dilution factors, as shown in Table 4.6. The Savuka Mineral Reserves and associated modifying factors were reported separately until 2012, as shown in Table 4.7.

Table 4.6: AGA: Tau Tona Mineral Reserves 2000-2016

Tau Tona Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2016	0.21	0.56	0.77	8.71	8.14	111	51.8%	75.4%	97.0%
2015	0.21	0.84	1.05	7.91	7.85	115	58.8%	73.8%	97.1%
2014	0.13	1.07	1.20	8.09	8.44	107	61.8%	73.6%	96.9%
2013	0.19	1.20	1.39	9.06	8.56	110	61.2%	71.7%	97.3%
2012	0.26	1.39	1.65	9.26	7.89	107	56.7%	79.1%	97.5%
2011	0.28	1.64	1.92	9.40	9.86	96	60.3%	81.7%	97.4%
2010	0.16	1.90	2.06	9.08	10.60	113	58.2%	81.6%	97.2%
2009	0.12	2.61	2.73	9.41	9.56	102	95.4%	82.0%	97.8%
2008	0.13	2.95	3.08	9.48	7.66	97	109.2%	81.2%	97.8%
2007	0.17	4.45	4.62	10.80	11.01	100	101.0%	78.0%	98.0%
2006	0.22	4.77	4.99	11.27	10.27	97	115.0%	78.0%	98.0%
2005	0.30	4.90	5.20	10.96	11.34	97	110.0%	79.7%	97.7%
2004	0.40	5.20	5.60	10.96	6.19	95	118.0%	85.0%	97.8%
2003	0.70	5.90	6.60	11.38	11.36	97	111.0%	89.0%	97.8%
2002	1.10	5.20	6.30	10.57	11.38	95	19.0%	90.0%	97.6%
2001	0.86	4.65	5.51	12.32	17.40	NR	NR	NR	NR
2000	0.79	2.39	3.18	11.24	16.60	NR	NR	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

Table 4.7: AGA: Savuka Mineral Reserves 2000-2012

Savuka Mineral Reserves**									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2012	0.05	0.50	0.55	5.13	7.50	120	63.1%	60.1%	97.3%
2011	0.00	0.60	0.60	7.90	7.50	100	56.0%	60.0%	97.4%
2010	0.01	0.66	0.67	6.18	7.96	113	73.3%	63.0%	97.0%
2009	0.02	0.67	0.69	6.17	7.96	113	63.7%	63.5%	97.3%
2008	0.01	0.75	0.76	6.59	7.96	113	80.7%	62.7%	97.5%
2007	0.02	0.67	0.69	6.64	8.18	110	56.0%	70.0%	97.0%
2006	0.11	0.07	0.18	5.69	7.63	118	47.0%	72.0%	97.0%
2005	0.00	0.10	0.10	8.74	8.74	103	45.0%	80.0%	97.6%
2004	0.00	0.40	0.40	7.31	7.47	107	53.0%	89.0%	97.6%
2003	0.10	0.30	0.40	6.77	4.61	108	44.0%	92.0%	97.7%
2002	0.20	2.50	2.70	6.61	4.39	114	49.0%	90.0%	97.5%
2001	0.23	1.24	1.47	6.71	11.92	NR	NR	NR	NR
2000	0.23	0.32	0.55	8.66	13.16	NR	NR	NR	NR

** - Closed in 2012, with transfer of Mineral Reserves to Tau Tona.
Source: Anglo Gold Ashanti (2000-2016)

AGA's Surface Operations produce gold from low grade surface stockpiles and through the re-treatment of tailings storage facility (TSF) dams. AGA's gold production from surface sources began in 2002 and increased further in 2012, with AGA's acquisition of the Mine Waste Service (MWS) tailings retreatment operation, which forms part of the Surface Operations (Anglo Gold Ashanti, 2016). Due to the nature of the Surface Operations, the stoping width and dilution modifying factors are not applicable to the Mineral Reserves. The consistent reporting of cut-off grade and MCF for the Surface Operations Mineral Reserves only started in 2006 and 2008, respectively, while metallurgical recoveries were consistently reported from 2002, as shown in Table 4.8

Table 4.8: AGA: Surface Operations Mineral Reserves 2000-2016

Surface Operations Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2016	0.92	5.47	6.39	0.26	0.25	N/A	N/A	100.0%	48.2%
2015	0.79	5.54	6.33	0.26	0.24	N/A	N/A	100.0%	49.1%
2014	0.86	5.73	6.59	0.26	0.21	N/A	N/A	100.0%	50.0%
2013	1.00	5.89	6.89	0.27	0.20	N/A	N/A	100.0%	60.7%
2012	1.05	6.12	7.17	0.29	0.26	N/A	N/A	99.7%	55.7%
2011	0.00	4.96	4.96	0.34	0.26	N/A	N/A	77.4%	78.5%
2010	0.00	1.74	1.74	0.49	0.38	N/A	N/A	99.2%	60.4%
2009	0.00	1.92	1.92	0.49	0.36	N/A	N/A	100.0%	77.6%
2008	0.00	1.95	1.95	0.51	0.30	N/A	N/A	100.0%	76.9%
2007	0.00	1.92	1.92	0.50	0.35	N/A	N/A	NR	76.0%
2006	0.00	1.91	1.91	0.57	0.41	N/A	N/A	NR	74.0%
2005	0.00	2.30	2.30	0.61	NR	N/A	N/A	NR	73.1%
2004	0.20	2.80	3.00	0.57	0.44	N/A	N/A	NR	74.3%
2003	0.50	2.80	3.30	0.54	NR	N/A	N/A	NR	74.3%
2002	0.90	2.40	3.30	0.59	NR	N/A	N/A	NR	73.1%
2001	0.51	2.20	2.71	0.55	NR	N/A	N/A	NR	NR
2000	1.71	0.48	2.19	0.44	NR	N/A	N/A	NR	NR

Source: Anglo Gold Ashanti (2000-2016)

Tau Lekoa is a former AGA operation which operated at a depth of 1,700m exploiting the VCR, and was sold in 2009 (Anglo Gold Ashanti, 2009). The Tau Lekoa Mineral Reserves were reported by AGA up to 2009, as shown in Table 4.9.

Table 4.9: AGA: Tau Lekoa Mineral Reserves 2000-2009

Tau Lekoa Mineral Reserves***									
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Stoping Width (cm)	Dilution (%)	MCF (%)	Met Recov. (%)
2009	0.04	0.76	0.80	3.90	2.78	144	29.0%	84.3%	97.4%
2008	0.16	0.76	0.92	3.88	2.78	144	31.0%	84.3%	97.4%
2007	0.29	1.00	1.29	3.52	7.09	141	30.0%	84.0%	97.0%
2006	0.32	1.01	1.33	4.07	7.14	140	18.0%	82.0%	97.0%
2005	0.50	0.50	1.00	4.11	5.07	163	22.0%	84.7%	96.7%
2004	0.70	2.20	2.90	3.98	5.32	156	23.0%	87.0%	96.7%
2003	1.20	2.60	3.80	4.27	4.77	151	19.0%	86.0%	96.4%
2002	0.90	3.00	3.90	3.99	4.00	163	23.0%	83.0%	95.5%
2001	1.02	2.22	3.24	4.55	4.78	NR	NR	NR	NR
2000	0.70	1.90	2.60	4.93	5.72	NR	NR	NR	NR

*** - Held for sale in 2009.
Source: Anglo Gold Ashanti (2000-2016)

Harmony Gold Mining Company Limited (Harmony) is another of the major South African gold mining companies that has undertaken relatively comprehensive Mineral Reserve reporting between 2000 and 2016. Harmony has operations in South Africa and Papua New Guinea. Table 4.10 shows the total Harmony Mineral Reserves from 2000 to 2016, and Table 4.11 to Table 4.19 show the Mineral Reserves for the Harmony South African operations over the period. While Harmony has reported the long-term gold price used in its Mineral Reserve estimates consistently from 2000 to 2016, as shown in Table 4.10, the reporting of the other modifying factors has been less consistent; as shown in Table 4.11 to Table 4.19. It

is worth noting that in addition to the common modifying factors reported by South African gold mining companies, Harmony reports a "milling width" modifying factors. Harmony defines milling width as "*a calculated width expressing the relationship between the total reef area excavated and the total tonnes milled from underground sources*" (Harmony, 2016, pp.84).

Table 4.10: Harmony: Total Harmony Mineral Reserves 2000-2016

HARMONY GOLD						
Harmony Gold Total Mineral Reserves						
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Gold Price (USD/oz)	Gold Price (ZAR/kg)
2016	9.44	13.56	23.00	0.65	1 150	475 107
2015	10.71	18.39	29.10	0.78	1 230	450 026
2014	13.32	22.40	35.72	0.76	1 300	425 064
2013	13.80	23.91	37.71	1.02	1 400	400 148
2012	13.93	25.14	39.07	0.96	1 400	339 833
2011	14.11	27.51	41.62	1.06	1 150	279 888
2010	11.02	37.08	48.10	1.04	950	250 149
2009	15.98	32.17	48.15	1.24	750	224 975
2008	13.33	37.15	50.48	1.46	750	179 883
2007	12.35	41.31	53.66	3.09	520	115 022
2006	13.61	42.42	56.03	4.76	500	104 972
2005	12.56	41.58	54.14	5.57	380	91 996
2004	20.91	41.35	62.26	5.06	380	91 996
2003	22.20	39.80	62.00	5.10	350	92 948
2002	18.20	30.88	49.08	5.59	295	94 845
2001	16.47	16.06	32.53	5.46	262	67 388
2000	14.29	12.72	27.01	5.31	275	60 033

Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Kusasalethu mine (formerly known as Elandsrand) is a deep level gold mine in the Carletonville area with operations reaching a depth of 3,048m. Kusasalethu began operating in 1984 and mines the VCR using the sequential grid mining method (Harmony, 2016). The Kusasalethu Mineral Reserves have been reported publicly by Harmony since 2001 but the technical modifying factors were only reported from 2005 onwards, with the exception of the plant recovery which was reported from 2001. Reporting gaps have occurred in the period for the plant recovery, while percentage extraction was not reported beyond 2007. From 2011 onwards, the cut-off grade and cost modifying factors for the Kusasalethu Mineral Reserves were reported (Table 4.11).

Table 4.11: Harmony: Kusasalethu Mineral Reserves 2001-2016

Kusasalethu Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov. Factor (%)	Extraction (%)
2016	0.88	0.04	0.92	7.06	1 073	2 857	132	158	NR	85.0%	93.0%	NR
2015	1.42	3.86	5.28	6.18	813	1 874	130	154	NR	85.0%	96.0%	NR
2014*	2.06	4.78	6.84	5.41	736	1 532						
2013	2.09	4.86	6.95	5.97	670	1 398	125	164	NR	86.0%	96.0%	NR
2012	2.70	4.41	7.11	6.30	771	1 229	126	159	NR	87.0%	96.0%	NR
2011	2.79	4.38	7.17	6.61	782	1 172	126	161	NR	87.0%	96.0%	NR
2010	2.68	4.83	7.51	6.51	NR	NR	129	158	NR	87.0%	96.0%	NR
2009	2.40	5.15	7.55	6.23	NR	NR	129	160	NR	87.0%	96.0%	NR
2008	0.90	7.73	8.63	6.66	NR	NR	132	169	NR	88.0%	96.0%	NR
2007	1.57	6.71	8.28	8.12	NR	NR	122	143	NR	90.0%	97.0%	64.0%
2006	1.25	5.91	7.16	7.57	NR	NR	134	149	NR	88.0%	NR	69.0%
2005	1.18	6.48	7.66	9.28	NR	NR	133	154	NR	88.0%	NR	65.0%
2004	3.06	5.69	8.75	8.17	NR	NR	NR	NR	NR	NR	95.6%	NR
2003	4.04	6.09	10.13	7.90	NR	NR	NR	NR	NR	NR	95.6%	NR
2002	4.75	7.47	12.22	7.01	NR	NR	NR	NR	NR	NR	97.0%	NR
2001	4.77	5.39	10.16	7.10	NR	NR	NR	NR	NR	NR	97.0%	NR

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Kalgold open pit gold mine, located in the North West province, is a unique South African gold operation. Kalgold's mineralisation is in the form of several gold lode deposits, which are banded iron formation-hosted greenstone gold deposits (Harmony, 2016). The Kalgold Mineral Reserves have been reported consistently from 2000 to 2016, as shown in Table 4.12. Technical modifying factors were mostly reported from 2005, with some reporting gaps and discontinuations and the introduction of cut-off grade reporting from 2011. The stoping and milling width modifying factors are not applicable to Kalgold, as it is a surface operation

Table 4.12: Harmony: Kalgold Mineral Reserves 2000-2016

Kalgold Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Factor (%)	Extraction (%)
2016	0.17	0.44	0.61	1.07	0.54	375	N/A	N/A	3.0%	100.0%	85.0%	N/A
2015	0.18	0.39	0.57	1.08	0.54	164	N/A	N/A	3.5%	100.0%	85.0%	N/A
2014*	0.20	0.34	0.54	0.88	NR	NR	N/A	N/A				N/A
2013	0.38	0.38	0.76	0.99	0.50	209	N/A	N/A	3.0%	100.0%	85.0%	N/A
2012	0.06	0.51	0.57	0.95	0.48	190	N/A	N/A	3.0%	100.0%	85.0%	N/A
2011	0.49	0.19	0.68	0.83	0.56	173	N/A	N/A	2.0%	100.0%	85.0%	N/A
2010	0.58	0.26	0.84	0.88	NR	NR	N/A	N/A	2.0%	100.0%	85.0%	N/A
2009	0.43	0.31	0.74	0.93	NR	NR	N/A	N/A	2.0%	100.0%	90.0%	N/A
2008	0.33	0.07	0.40	0.95	NR	NR	N/A	N/A	2.0%	100.0%	90.0%	N/A
2007	0.12	0.23	0.35	1.42	NR	NR	N/A	N/A	2.0%	100.0%	85.0%	N/A
2006	0.09	0.25	0.34	1.24	NR	NR	N/A	N/A	10.0%	100.0%	NR	N/A
2005	0.05	0.11	0.16	2.02	NR	NR	N/A	N/A	10.0%	100.0%	NR	N/A
2004	0.38	0.00	0.38	2.11	NR	NR	N/A	N/A	NR	NR	82.0%	N/A
2003	0.50	0.05	0.55	2.00	NR	NR	N/A	N/A	NR	NR	85.0%	N/A
2002	0.47	0.13	0.60	2.10	NR	NR	N/A	N/A	NR	NR	82.0%	N/A
2001	0.36	0.09	0.45	1.91	NR	NR	N/A	N/A	NR	NR	89.0%	N/A
2000	0.48	0.12	0.60	2.37	NR	NR	N/A	N/A	NR	NR	89.0%	N/A

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Tshepong, Phakisa, Bamabanani, Joel, St Helena and West operations are part of the Free Gold operations which were the result of a joint venture between Harmony and ARMgold Limited in 2002 (Harmony, 2002). The Free Gold operations are located around the town of Welkom in the Free State province and primarily exploit the Basal Reef, with the exception of Joel, which extracts the Beatrix/VS5 Reef. Tshepong, Phakisa, Bambanani and West are separated by north-south trending faults with shallow dips trending to the east (Harmony, 2005). Only Tshepong, Phakisa, Bamabanani and Joel operations were still operational in 2016. Tshepong is a deep-level mine operating between 1,600m to 2,200m below surface, where the Basal Reef is undercut through conventional grid development and the B Reef is extracted through open stoping methods. Phakisa exploits the Basal Reef through conventional grid development and was still in a ramp-up phase in 2016. Bambanani is a mature operation, where mining is limited to the extraction of the shaft pillar between 1,911m and 2,197m. Joel is a moderate depth gold mine, exploiting the Beatrix Reef at depths of around 1,300m below surface via conventional narrow-reef mining methods (Harmony, 2016).

Prior to 2005, the Free Gold operations Mineral Reserves were reported on a consolidated basis, but from 2005 to 2016 Harmony increased the granularity of its reporting with each operation being reported individually in this period. Table 4.13 to Table 4.18 show the granular operation reporting of the Free Gold assets from 2005 to 2016, while Table 4.19 shows the initial consolidated reporting of the Free Gold operations pre-2005. In the period between 2005 and 2006 the MCF, plant recovery factor, stoping width and milling width modifying factors were reported for each of the Free Gold operations for most of the period (Table 4.13 to Table 4.18). Percentage extraction was only reported up until 2007, while cut-off grade and cost were reported from 2011 onwards. Between 2002 and 2004, only the plant recovery modifying factor was reported for the Free Gold operations, as shown in Table 4.19.

Table 4.13: Harmony: Tshepong Mineral Reserves 2005-2016

Tshepong Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	3.02	0.50	3.52	5.30	650	2 014	105	131	NR	71.0%	96.0%	NR
2015	3.29	0.47	3.76	5.42	650	1 781	105	131	NR	71.0%	96.0%	NR
2014*	3.68	0.42	4.10	5.04	650	1 619						
2013	3.26	0.55	3.81	5.39	650	1 514	105	130	NR	71.0%	96.0%	NR
2012	3.23	0.63	3.86	5.44	650	1 138	105	128	NR	72.0%	96.0%	NR
2011	2.30	1.38	3.68	5.24	650	1 069	105	141	NR	69.0%	96.0%	NR
2010	2.25	1.63	3.88	5.34	NR	NR	105	130	NR	66.0%	96.0%	NR
2009	2.18	2.13	4.31	5.53	NR	NR	105	142	NR	65.0%	97.0%	NR
2008	1.18	3.39	4.57	6.03	NR	NR	103	141	NR	68.0%	97.0%	NR
2007	1.43	3.72	5.15	7.14	NR	NR	103	139	NR	73.0%	97.0%	79%
2006	1.62	3.82	5.44	7.06	NR	NR	103	137	NR	74.0%	NR	82%
2005	1.64	4.40	6.04	7.09	NR	NR	102	138	NR	77.0%	NR	78%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.14: Harmony: Phakisa Mineral Reserves 2005-2016

Phakisa Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	1.19	0.44	1.63	6.72	790	2 360	119	145	NR	80.0%	96.0%	NR
2015	1.29	0.50	1.79	6.83	790	1 985	122	145	NR	80.0%	96.0%	NR
2014*	0.70	0.99	1.69	6.31	790	1 716						
2013	0.97	3.59	4.56	7.04	790	1 541	120	146	NR	80.0%	96.0%	NR
2012	0.74	4.15	4.89	7.79	640	1 367	119	142	NR	80.0%	96.0%	NR
2011	0.42	4.74	5.16	8.42	600	1 073	110	139	NR	84.0%	96.0%	NR
2010	0.09	5.07	5.16	8.02	NR	NR	106	127	NR	82.0%	96.0%	NR
2009	0.06	5.24	5.30	8.05	NR	NR	100	129	NR	81.0%	95.0%	NR
2008	0.03	5.30	5.33	8.31	NR	NR	100	129	NR	81.0%	97.0%	NR
2007	0.02	5.38	5.40	8.41	NR	NR	100	129	NR	85.0%	97.0%	80%
2006	0.00	5.27	5.27	8.33	NR	NR	100	129	NR	83.0%	NR	80%
2005	0.00	3.96	3.96	7.38	NR	NR	100	127	NR	83.0%	NR	76%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.15: Harmony: Bambanani Mineral Reserves 2005-2016

Bambanani Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	0.45	0.00	0.45	11.08	1 781	3 690	180	222	NR	96.0%	96.0%	NR
2015	0.57	0.00	0.57	11.33	1 491	2 753	183	226	NR	96.0%	96.0%	NR
2014*	0.65	0.00	0.65	9.58	1 420	2 105						
2013	0.84	0.00	0.84	11.08	1 935	2 022	212	255	NR	92.0%	96.0%	NR
2012	0.95	0.00	0.95	12.76	1 687	1 925	183	212	NR	82.0%	96.0%	NR
2011	1.20	0.01	1.21	11.36	1 600	1 640	186	212	NR	82.0%	96.0%	NR
2010	1.41	0.30	1.71	10.71	NR	NR	187	206	NR	82.0%	96.0%	NR
2009	0.97	0.42	1.39	9.09	NR	NR	200	218	NR	78.0%	96.0%	NR
2008	0.89	0.29	1.18	9.58	NR	NR	187	213	NR	76.0%	95.0%	NR
2007	1.37	0.63	2.00	7.39	NR	NR	202	239	NR	78.0%	95.0%	77%
2006	1.57	0.56	2.13	7.44	NR	NR	192	219	NR	80.0%	NR	59%
2005	1.25	1.21	2.46	8.01	NR	NR	179	209	NR	85.0%	NR	76%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.16: Harmony: Joel Mineral Reserves 2005-2016

Joel Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	0.44	0.44	0.88	4.91	772	1 899	161	194	NR	84.0%	95.0%	NR
2015	0.35	0.62	0.97	5.24	800	1 530	157	193	NR	84.0%	96.0%	NR
2014*	0.40	0.82	1.22	5.13	800	1 573						
2013	0.30	0.68	0.98	5.45	800	1 360	162	195	NR	83.0%	96.0%	NR
2012	0.26	0.72	0.98	5.20	806	1 140	155	185	NR	83.0%	96.0%	NR
2011	0.27	0.26	0.53	5.58	748	978	153	183	NR	86.0%	95.0%	NR
2010	0.24	0.26	0.50	5.90	NR	NR	150	176	NR	88.0%	95.0%	NR
2009	0.16	0.40	0.56	5.58	NR	NR	150	198	NR	93.0%	96.0%	NR
2008	0.12	0.32	0.44	5.04	NR	NR	150	185	NR	88.0%	96.0%	NR
2007	0.12	0.50	0.62	5.14	NR	NR	142	182	NR	85.0%	96.0%	83%
2006	0.27	0.11	0.38	5.22	NR	NR	142	167	NR	86.0%	NR	74%
2005	0.10	0.17	0.27	4.28	NR	NR	148	156	NR	80.0%	NR	83%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.17: Harmony: St Helena 8 Mineral Reserves 2005-2007

St Helena 8 Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2007	0.08	0.05	0.13	4.23	NR	NR	191	235	NR	68.0%	95.1%	67%
2006	0.13	0.06	0.19	5.98	NR	NR	168	186	NR	85.0%	NR	46%
2005	0.21	0.03	0.24	5.15	NR	NR	182	227	NR	88.0%	NR	56%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.18: Harmony: West Mineral Reserves 2005-2006

West Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2006	0.10	0.09	0.19	6.36	NR	NR	175	196	NR	80.0%	NR	38%
2005	0.25	0.04	0.29	6.42	NR	NR	158	155	NR	80.0%	NR	76%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.19: Harmony: Free Gold Mineral Reserves 2002-2004

Free Gold Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2004	5.82	11.85	17.67	5.63	NR	NR	NR	NR	NR	NR	97.0%	NR
2003	3.08	6.70	9.78	5.74	NR	NR	NR	NR	NR	NR	97.0%	NR
2002	2.41	4.33	6.74	5.79	NR	NR	NR	NR	NR	NR	97.0%	NR

Source: Harmony Gold Mining Company Limited (2000-2016)

The Harmony Free State operations consist of the Unisel, Masimong, Merriespruit, Harmony 2 and Brand 3 mines, of which only Unisel and Masimong were still operational in 2016. Unisel is a mature operation, exploiting the Leader, Basal and Middle reefs at depths between 1,100m to 2,100m below surface and 2km to 4km from the shaft, using conventional scattered breast mining methods. Masimong is a marginal mine operating at depths between 1,650m to 2,010m, exploiting the Basal

and B Reefs, with access conventional grid development (Harmony, 2016). From 2000 to 2004, the Free State operations were reported on a consolidated basis, followed by granular reporting per operation from 2005 onwards. Table 4.20 to Table 4.24 show the granular reporting per operation post-2004, while Table 4.25 shows the consolidated reporting of the Free State operations pre-2005. The modifying factors were reported for each operation post-2004, while the only the plant recovery factor was reported for the Free State operations pre-2005.

Table 4.20: Harmony: Unisel Mineral Reserves 2005-2016

Unisel Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	0.17	0.18	0.35	4.27	945	1 894	190	215	NR	75.0%	96.0%	NR
2015	0.27	0.11	0.38	4.48	880	1 571	190	209	NR	75.0%	96.0%	NR
2014*	0.22	0.08	0.30	3.82	1 115	1 645						
2013	0.29	0.11	0.40	4.30	1 100	1 367	187	200	NR	75.0%	96.0%	NR
2012	0.27	0.15	0.42	4.63	723	1 258	180	194	NR	77.0%	96.0%	NR
2011	0.29	0.15	0.44	4.65	975	1 000	179	191	NR	75.0%	96.0%	NR
2010	0.35	0.21	0.56	4.70	NR	NR	186	203	NR	76.0%	95.0%	NR
2009	0.48	0.28	0.76	4.91	NR	NR	175	193	NR	80.0%	95.0%	NR
2008	0.31	0.27	0.58	5.41	NR	NR	165	179	NR	82.0%	93.0%	NR
2007	0.30	0.36	0.66	5.27	NR	NR	175	191	NR	85.0%	93.0%	70%
2006	0.35	0.39	0.74	5.87	NR	NR	168	166	NR	85.0%	NR	68%
2005	0.46	0.39	0.85	5.10	NR	NR	177	188	NR	83.0%	NR	84%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.21: Harmony: Masimong Mineral Reserves 2005-2016

Masimong Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	0.19	0.03	0.22	4.02	906	1 887	136	154	NR	66.0%	96.0%	NR
2015	0.21	0.02	0.23	3.85	906	1 578	140	160	NR	63.0%	96.0%	NR
2014*	0.71	0.24	0.95	4.04	903	1 485						
2013	0.90	0.37	1.27	4.76	850	1 232	135	153	NR	68.0%	96.0%	NR
2012	0.91	0.21	1.12	5.06	890	1 087	133	152	NR	69.0%	96.0%	NR
2011	0.91	0.25	1.16	5.44	942	1 019	133	153	NR	69.0%	96.0%	NR
2010	0.89	0.31	1.20	5.10	NR	NR	135	156	NR	68.0%	96.0%	NR
2009	0.75	0.23	0.98	5.22	NR	NR	130	154	NR	67.0%	95.0%	NR
2008	0.59	0.17	0.76	5.08	NR	NR	133	148	NR	62.0%	96.0%	NR
2007	0.99	0.73	1.72	5.86	NR	NR	135	148	NR	75.0%	96.0%	99%
2006	1.44	1.44	2.88	4.88	NR	NR	160	175	NR	76.0%	NR	76%
2005	1.04	2.00	3.04	4.84	NR	NR	154	183	NR	76.0%	NR	82%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.22: Harmony: Merriespruit Mineral Reserves 2005-2010

Merriespruit Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2010	0.06	0.01	0.07	3.94	NR	NR	173	214	NR	68.0%	94.0%	NR
2009	0.29	0.10	0.39	4.15	NR	NR	183	221	NR	72.0%	95.0%	NR
2008	0.29	0.05	0.34	3.82	NR	NR	178	209	NR	0.65	0.95	NR
2007	0.17	0.19	0.36	4.60	NR	NR	188	212	NR	71.0%	95.0%	62%
2006	0.45	0.33	0.78	4.39	NR	NR	189	204	NR	73.0%	NR	59%
2005	0.47	0.44	0.91	3.94	NR	NR	186	204	NR	70.0%	NR	75%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.23: Harmony: Harmony 2 Mineral Reserves 2005-2009

Harmony 2 Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2009	0.10	0.01	0.11	3.53	NR	NR	154	178	NR	69.0%	95.0%	NR
2008	0.08	0.03	0.11	3.63	NR	NR	151	171	NR	68.0%	95.1%	NR
2007	0.11	0.02	0.13	4.46	NR	NR	176	196	NR	72.0%	95.0%	71%
2006	0.13	0.15	0.28	4.49	NR	NR	175	189	NR	66.0%	NR	97%
2005	0.09	0.02	0.11	4.92	NR	NR	184	188	NR	69.0%	NR	85%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.24: Harmony: Brand 3 Mineral Reserves 2005-2009

Brand 3 Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2009	0.07	0.02	0.09	4.02	NR	NR	193	229	NR	94.0%	96.0%	NR
2008	0.07	0.03	0.10	4.23	NR	NR	175	214	NR	95.0%	94.6%	NR
2007	0.07	0.01	0.08	4.43	NR	NR	182	222	NR	90.0%	94.3%	75%
2006	0.02	0.02	0.04	4.60	NR	NR	158	182	NR	80.0%	NR	14%
2005	0.10	0.08	0.18	4.85	NR	NR	179	191	NR	76.0%	NR	85%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.25: Harmony: Free State Operations Mineral Reserves 2000-2004

Free State Operations Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2004	3.82	2.71	6.53	4.46	NR	NR	NR	NR	NR	NR	95.0%	NR
2003	3.90	3.22	7.12	4.60	NR	NR	NR	NR	NR	NR	95.0%	NR
2002	4.75	2.56	7.31	4.55	NR	NR	NR	NR	NR	NR	95.0%	NR
2001	4.58	2.22	6.80	4.78	NR	NR	NR	NR	NR	NR	95.0%	NR
2000	5.68	2.11	7.79	5.33	NR	NR	NR	NR	NR	NR	95.0%	NR

Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Free State Surface Operations Mineral Reserves consists of TSFs and waste rock dumps. A tailings re-treatment project was implemented in 2007 for the processing of these Mineral Reserves in the form of the Phoenix operation. In 2016 the implementation of the Central Plant conversion for tailings re-treatment was approved, to further increase tailings re-treatment capacity for the Free State Surface Operations (Harmony, 2016). Although the Mineral Reserves for the Free

State Surface Operations (Table 4.26) have been reported since 2002, the MCF modifying factor was only reported from 2005, followed by the reporting of the plant recovery factor from 2009; after the implementation of the Phoenix project. Cut-off grade and cost modifying factor reporting was introduced in 2011.

Table 4.26: Harmony: Free State Surface Operations Mineral Reserves 2002-2016

Free State Surface Operations Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	2.22	4.28	6.50	0.25	0.15	45	N/A	N/A	NR	100.0%	49.8%	N/A
2015	2.30	4.19	6.49	0.25	0.17	47	N/A	N/A	NR	100.0%	49.8%	N/A
2014*	3.10	4.40	7.50	0.25			N/A	N/A				N/A
2013	3.18	3.06	6.24	0.26	0.14	34	N/A	N/A	NR	100.0%	49.0%	N/A
2012	3.21	3.88	7.09	0.25	0.14	34	N/A	N/A	NR	100.0%	50.0%	N/A
2011	3.11	4.31	7.42	0.24	0.13	25	N/A	N/A	NR	100.0%	50.0%	N/A
2010	0.00	7.21	7.21	0.24	NR	NR	N/A	N/A	NR	100.0%	55.0%	N/A
2009	6.46	0.85	7.31	0.24	NR	NR	N/A	N/A	NR	100.0%	47.0%	N/A
2008	5.68	0.80	6.48	0.25	NR	NR	N/A	N/A	NR	100.0%	NR	N/A
2007	1.76	0.21	1.97	0.30	NR	NR	N/A	N/A	NR	100.0%	NR	N/A
2006	0.82	0.19	1.01	0.41	NR	NR	N/A	N/A	NR	100.0%	NR	N/A
2005	0.32	0.20	0.52	0.42	NR	NR	N/A	N/A	NR	100.0%	NR	N/A
2004	0.17	0.48	0.65	0.54	NR	NR	N/A	N/A	NR	NR	NR	N/A
2003	0.18	0.24	0.42	0.48	NR	NR	N/A	N/A	NR	NR	NR	N/A
2002	0.34	0.08	0.42	0.77	NR	NR	N/A	N/A	NR	NR	NR	N/A

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Randfontein Operations consisted of the Doornkop and Cooke operations. Doornkop is located 30km west of Johannesburg and exploits the South Reef through conventional narrow-reef methods to a depth of approximately 2,000m below surface. The Kimberly Reef was previously mined at Doornkop but was suspended in 2014, and may resume in the future depending on economic conditions (Harmony, 2016). The Cooke 1, 2 and 3 operations targeted UE1A and the Elsburg A5 Reefs, while Cooke 4 mined 10 different reefs, including the Mondeor, Elsburg and VCR Reefs (Harmony, 2005). Harmony's interest in the Cooke operations was sold to Pamodzi Resources Fund in November 2008 (Harmony, 2008). The Mineral Reserves for Doornkop and Cooke were only reported in detail from 2005 onwards as shown in Table 4.27 and Table 4.28. Prior to that reporting was on a consolidated basis (Table 4.29). The modifying factors were reported in detail post-2004, while pre-2005 only the plant recovery factor was reported. The Randfontein Surface Stockpile Mineral Reserves (Table 4.30) were associated with the Cooke operations and were only reported from 2000 to 2007, prior to the disposal of the Cooke operations. Only the plant recovery modifying

factor for the Randfontein Surface Stockpile Mineral Reserves was reported from 2005 to 2007, prior to that none of the relevant modifying factors were reported.

Table 4.27: Harmony: Doornkop Mineral Reserves 2005-2016

Doornkop Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov. Factor (%)	Extraction (%)
2016	0.28	0.43	0.71	5.14	735	1 985	125	147	NR	81.0%	97.0%	NR
2015	0.21	0.64	0.85	5.16	680	1 622	121	153	NR	82.0%	96.0%	NR
2014*	0.42	0.90	1.32	4.91	650	1 392			NR			NR
2013	0.36	0.86	1.22	4.99	646	1 206	218	246	NR	87.0%	96.0%	NR
2012	0.45	0.68	1.13	3.78	716	850	247	267	NR	88.0%	95.0%	NR
2011	0.32	0.63	0.95	3.39	676	598	267	283	NR	88.0%	95.0%	NR
2010	0.16	0.28	0.44	3.50	NR	NR	271	285	NR	85.0%	95.0%	NR
2009	0.07	0.15	0.22	3.75	NR	NR	213	238	NR	81.0%	95.0%	NR
2008	0.04	0.14	0.18	4.20	NR	NR	212	230	NR	87.0%	95.0%	NR
2007	0.02	0.35	0.37	6.64	NR	NR	147	162	NR	76.0%	95.0%	85.0%
2006	0.04	0.32	0.36	6.07	NR	NR	186	210	NR	75.0%	NR	82.0%
2005	0.08	0.37	0.45	6.07	NR	NR	124	154	NR	76.0%	NR	85.0%

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.28: Harmony: Cooke Mineral Reserves 2005-2007

Cooke Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2007	0.78	0.47	1.25	6.81	NR	NR	198	202	NR	73.0%	96.4%	65%
2006	0.96	0.94	1.90	6.54	NR	NR	165	182	NR	65.0%	NR	67%
2005	0.86	1.38	2.24	5.09	NR	NR	182	209	NR	63.6%	NR	75%

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.29: Harmony: Randfontein Operations Mineral Reserves 2000-2004

Randfontein Operations Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2004	1.61	0.99	2.60	5.55	NR	NR	NR	NR	NR	NR	96.5%	NR
2003	2.71	1.48	4.19	4.90	NR	NR	NR	NR	NR	NR	96.5%	NR
2002	3.10	1.51	4.61	5.64	NR	NR	NR	NR	NR	NR	96.0%	NR
2001	3.68	1.99	5.67	5.75	NR	NR	NR	NR	NR	NR	96.0%	NR
2000	4.41	3.92	8.33	5.13	NR	NR	NR	NR	NR	NR	96.0%	NR

Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.30: Harmony: Randfontein Surface Stockpile Mineral Reserves 2000-2007

Randfontein Surface Stockpile Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2007	0.08	0.00	0.08	0.70	NR	NR	N/A	N/A	N/A	100.0%	NR	N/A
2006	0.00	0.05	0.05	0.77	NR	NR	N/A	N/A	N/A	100.0%	NR	N/A
2005	0.05	0.02	0.07	0.87	NR	NR	N/A	N/A	N/A	90.0%	NR	N/A
2004	0.47	0.01	0.48	0.34	NR	NR	N/A	N/A	N/A	NR	NR	N/A
2003	0.53	0.00	0.53	0.69	NR	NR	N/A	N/A	N/A	NR	NR	N/A
2002	0.04	0.07	0.11	0.99	NR	NR	N/A	N/A	N/A	NR	NR	N/A
2001	0.02	0.04	0.06	1.71	NR	NR	N/A	N/A	N/A	NR	NR	N/A
2000	0.05	0.10	0.15	1.54	NR	NR	N/A	N/A	N/A	NR	NR	N/A

Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony acquired the Target 1 mine following its acquisition of Avgold Limited in 2004 (Harmony, 2004). Target 1 is located 20km from Welkom and exploits the Elsburg-Dreyerskuil conglomerates, which are reef packages that are exploited through massive mining methods (Harmony, 2005). Target 3, formerly known as Loraine 3, was acquired from Pamodzi FS in 2010 and incorporated into the Target operations. Target 3 is a mature mine which presented opportunities for remnant mining using conventional scattered mining as well as virgin ground mining via conventional methods and massive mining similar to Target 1 (Harmony, 2010). Target 3 was placed on care and maintenance in the December 2014 quarter due to poor financial performance and high capital requirements (Harmony, 2015). The Mineral Reserves for Target 1 were reported with only the plant recovery modifying factors at acquisition in 2004 (Table 4.31). Additional modifying factors for Target 1 were reported from 2005, although there was a break in the reporting of the plant recovery factor in 2005 and 2006. Cut-off grade and cost modifying factor reporting for Target 1 was introduced in 2011. The Target 3 Mineral Reserves (Table 4.32) were mostly reported with detailed disclosure of the modifying factors from 2010 to 2014, prior to it being placed on care and maintenance.

Table 4.31: Harmony: Target 1 Mineral Reserves 2004-2016

Target 1 Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2016	0.40	0.59	0.99	4.69	3.60	1 890	N/A	N/A	NR	96.0%	96.0%	NR
2015	0.56	0.63	1.19	5.29	3.40	1 748	N/A	N/A	NR	99.0%	97.0%	NR
2014*	0.67	1.01	1.68	4.42	3.40	1 630						
2013	0.68	0.81	1.49	5.23	4.20	1 420	N/A	N/A	NR	103.0%	96.0%	NR
2012	0.53	1.02	1.55	4.90	4.25	1 178	N/A	N/A	NR	100.0%	95.0%	NR
2011	0.81	0.94	1.75	5.23	4.85	1 095	N/A	N/A	NR	100.0%	96.0%	NR
2010	0.70	1.10	1.80	4.84	NR	NR	N/A	N/A	NR	100.0%	96.0%	NR
2009	0.94	1.62	2.56	5.77	NR	NR	N/A	N/A	5.0%	95.0%	96.0%	NR
2008	1.97	2.28	4.25	6.64	NR	NR	N/A	N/A	6.0%	98.0%	96.0%	NR
2007	1.82	2.47	4.29	6.66	NR	NR	N/A	N/A	6.0%	97.0%	97.0%	NR
2006	1.89	2.43	4.32	6.96	NR	NR	N/A	N/A	5.0%	100.0%	NR	NR
2005	1.58	3.20	4.78	5.43	NR	NR	N/A	N/A	5.0%	95.0%	NR	NR
2004	1.88	3.56	5.44	6.98	NR	NR	N/A	N/A	NR	NR	97.5%	NR

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Table 4.32: Harmony: Target 3 Mineral Reserves 2010-2014

Target 3 Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2014*	0.47	0.68	1.15	4.88	850	1 700						
2013	0.55	0.72	1.27	5.89	690	1 519	122	141	NR	78.0%	96.0%	NR
2012	0.58	0.67	1.25	6.40	621	1 209	113	128	NR	75.0%	95.0%	NR
2011	0.43	0.56	0.99	6.11	701	1 102	118	141	NR	77.0%	96.0%	NR
2010	0.25	0.74	0.99	6.61	NR	NR	100	119	NR	76.0%	96.0%	NR

* - The 2014 annual and Mineral Resource and Mineral Reserves reports are no longer accessible on the Harmony website
Source: Harmony Gold Mining Company Limited (2000-2016)

Harmony's Evander operations are located near the town of Evander, in the Mpumalanga province. The Evander operations are located within the Evander Basin, which is a sub-basin outside the main Witwatersrand Basin. The Evander operations exploit the Kimberly Reef (Harmony, 2008). The Evander operations were sold to Pan African Resources plc in 2012 for a consideration of R1.5 billion (Harmony, 2012). The Evander Mineral Reserves were reported from 2000 to 2011 (Table 4.33), prior to their disposal by Harmony. Only the plant recovery modifying factor was reported pre-2005, thereafter more detailed reporting of the modifying factors occurred.

Table 4.33: Harmony: Evander Mineral Reserves 2000-2011

Evander Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2011	0.57	7.45	8.02	3.61	1 196	1 286	112	142	NR	91.0%	69.0%	NR
2010	0.52	12.62	13.14	1.60	NR	NR	111	140	NR	95.0%	54.0%	NR
2009	0.52	13.28	13.80	7.22	NR	NR	108	136	NR	80.0%	97.0%	NR
2008	0.62	13.53	14.15	7.09	NR	NR	113	134	NR	79.0%	97.0%	NR
2007	1.04	15.05	16.09	7.07	NR	NR	116	134	NR	79.0%	97.0%	82.0%
2006	1.17	13.36	14.53	7.63	NR	NR	114	137	NR	79.0%	NR	80.0%
2005	1.53	13.80	15.33	7.19	NR	NR	115	145	NR	76.0%	NR	81.0%
2004	2.42	13.39	15.81	6.86	NR	NR	NR	NR	NR	NR	96.7%	NR
2003	2.21	13.65	15.86	7.00	NR	NR	NR	NR	NR	NR	96.7%	NR
2002	1.97	12.93	14.90	7.42	NR	NR	NR	NR	NR	NR	96.0%	NR
2001	2.51	6.05	8.56	6.05	NR	NR	NR	NR	NR	NR	96.0%	NR
2000	3.51	6.19	9.70	6.11	NR	NR	NR	NR	NR	NR	96.0%	NR

Source: Harmony Gold Mining Company Limited (2000-2016)

The Orkney operations, located near the town of Orkney in the North West Province, were acquired by Harmony as part of its joint venture with ARMgold Limited in 2003 (Harmony, 2003). The Orkney shafts extracted the Vaal, VCR and Elsburg Reefs. The Orkney operations were sold to Pamodzi Gold Limited in 2007 for a consideration of R550 million (Harmony, 2007). The Mineral Reserves for the Orkney operations were reported from 2003, at acquisition, to 2006, prior to the 2007 disposal. None of the modifying factors were reported for the Orkney

operations in 2003 and 2004, thereafter more detailed reporting of the modifying factors was undertaken.

Table 4.34: Harmony: Orkney Mineral Reserves 2003-2006

Orkney Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Cut-off Cost (ZAR/t)	Stoping Width (cm)	Milling Width (cm)	Dilution (%)	MCF (%)	Plant Recov Fact. (%)	Extraction (%)
2006	0.84	0.46	1.30	5.99	NR	NR	129	164	NR	91.0%	NR	77%
2005	1.17	1.03	2.20	5.45	NR	NR	145	195	NR	84.7%	NR	86%
2004	0.82	0.13	0.95	7.91	NR	NR	NR	NR	NR	NR	NR	NR
2003	1.59	0.65	2.24	5.30	NR	NR	NR	NR	NR	NR	NR	NR

Source: Harmony Gold Mining Company Limited (2000-2016)

Between 2000 and 2016, Gold Fields operated the Beatrix Gold Mine, the Kloof and Driefontein Gold Mine (the Kloof-Driefontein Complex or KDC) and the South Deep Gold Mine in South Africa; as well as other gold mines in West Africa, Australia and South America. The Beatrix and KDC assets were unbundled and transferred to Sibanye Gold in 2012, leaving South Deep as the only operating Gold Fields South African asset (Gold Fields 2012). Gold Fields acquired South Deep in 2007 for a purchase consideration of USD2.5 billion (Gold Fields, 2007).

The KDC operations exploit the VCR, with minimal extraction of the Middelvlei and Kloof Reefs through scattered mining and mini-longwall mining methods. The Beatrix operations also make use of scattered narrow-reef mining methods, while South Deep employs drift and benching and long-hole stoping methods (Gold Fields, 2011). Table 4.35 shows the total Gold Fields Mineral Reserves from 2000 to 2016, while Table 4.36 to Table 4.38 show the Mineral Reserves for the South African operations over the period. Gold Fields began reporting its long-term gold price for Mineral Reserves conversion in 2001 (Table 4.35), a year after the introduction of the SAMREC Code. The cut-off grade, stoping width, MCF and metallurgical recovery modifying factors were reported for Beatrix and KDC in 2001 and 2002, however between 2003 and 2006 Gold Fields did not report modifying factors (except gold price) for these operations. From 2007 to 2011, Gold Fields re-introduced detailed reporting of modifying factors for Beatrix and KDC, although stoping width and MCF were only reported intermittently. Although the Mineral Reserves of South Deep were reported from 2007, detailed and consistent reporting of the modifying factors only occurred from 2011 (Table 4.36).

Table 4.35: Gold Fields: Total Gold Fields Mineral Reserves 2000-2016

GOLD FIELDS						
Gold Fields Total Mineral Reserves						
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Gold Price (USD/oz)	Gold Price (ZAR/kg)
2016	42.50	7.07	49.57	2.83	1 200	550 000
2015	42.21	6.74	48.95	2.92	1 300	500 000
2014	42.89	8.16	51.05	2.90	1 300	400 000
2013	43.36	8.73	52.09	2.90	1 300	400 000
2012	48.91	10.49	59.40	2.54	1 500	380 000
2011	58.26	20.86	79.12	2.40	1 300	310 000
2010	57.76	16.80	74.56	3.50	1 000	265 000
2009	61.02	21.80	82.82	3.50	800	230 000
2008	23.11	61.48	84.59	3.50	750	150 000
2007	24.23	72.18	96.41	3.60	650	100 000
2006	24.35	44.01	68.36	2.90	560	92 000
2005	23.87	40.80	64.67	3.40	560	92 000
2004	26.45	53.63	80.08	3.80	580	90 000
2003	28.42	55.35	83.77	4.60	580	95 000
2002	22.88	58.26	81.14	5.03	285	95 111
2001	26.40	59.72	86.12	6.40	270	69 992
2000	32.98	39.02	72.00	6.25	NR	NR

Source: Gold Fields (2000-2016)

Table 4.36: Gold Fields: South Deep Mineral Reserves 2007-2016

South Deep Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (g/t)	Dilution (%)	Mining Losses (%)	MCF (%)	Met Recovery (%)	Processing Capacity (Mtpa)	Mining Recovery (%)
2016	2.72	34.61	37.33	5.34	3.80	8%	6%	100%	97%	4.0	96%
2015	2.25	35.00	37.25	5.30	3.80	7%	4%	100%	97%	4.0	96%
2014	2.72	35.30	38.02	5.30	3.80	7%	4%	98%	97%	4.0	96%
2013	2.93	35.30	38.23	5.30	3.80	7%	4%	98%	97%	4.0	96%
2012	2.89	36.22	39.11	5.45	3.50	8%	3%	100%	97%	4.0	97%
2011	2.93	36.66	39.59	5.47	3.50	6%	3%	104%	97%	2.6	100%
2010	2.70	26.50	29.20	6.10	4.00	6%	NR	100%	97%	NR	NR
2009	2.91	26.58	29.49	6.10	4.00	NR	NR	NR	97%	NR	NR
2008	3.00	26.13	29.13	6.10	4.24	NR	NR	NR	97%	NR	NR
2007	2.75	27.83	30.58	6.10	3.90	NR	NR	NR	NR	NR	NR

Source: Gold Fields (2000-2016)

Table 4.37: Gold Fields: Beatrix Mineral Reserves 2000-2011

Beatrix Gold Mine Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Dilution (%)	Stoping Width (cm)	MCF (%)	Met Recovery (%)	Mining Recovery (%)
2011	3.44	1.52	4.96	3.90	920	23%	NR	79%	96%	76%
2010	1.59	4.16	5.75	4.60	840	23%	154	86%	96%	50%
2009	2.09	4.36	6.45	4.90	840	23%	NR	NR	96%	53%
2008	1.78	4.92	6.70	5.00	910	19%	NR	NR	96%	58%
2007	2.73	5.71	8.44	5.50	990	24%	NR	NR	96%	69%
2006	2.82	5.41	8.23	5.50	NR	NR	NR	NR	NR	NR
2005	2.53	5.68	8.21	5.40	NR	NR	NR	NR	NR	NR
2004	3.20	6.61	9.81	5.30	NR	NR	NR	NR	NR	NR
2003	3.62	8.56	12.18	4.90	NR	NR	NR	NR	NR	NR
2002	3.02	9.47	12.49	5.20	736	NR	180	90%	97%	NR
2001	4.19	10.02	14.21	6.50	677	NR	172	93%	97%	NR
2000	3.91	12.85	16.76	6.90	NR	NR	NR	NR	NR	NR

Source: Gold Fields (2000-2016)

Table 4.38: Gold Fields: Kloof-Driefontein Complex Mineral Reserves 2000-2011

Kloof-Driefontein Complex (KDC) Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Cut-Off Grade (cmg/t)	Dilution (%)	Stoping Width (cm)	MCF (%)	Met Recovery (%)	Mining Recovery (%)
2011	5.71	7.62	13.33	7.60	1 498	27%	NR	84%	97%	77%
2010	7.64	19.05	26.69	7.10	1 228	25%	149	89%	97%	79%
2009	8.86	19.86	28.72	6.96	1 224	24%	NR	NR	97%	80%
2008	10.17	20.60	30.77	7.29	1 494	24%	NR	NR	97%	71%
2007	9.84	25.07	34.91	8.18	1 767	21%	NR	NR	97%	70%
2006	11.49	25.42	36.91	7.69	NR	NR	NR	NR	NR	NR
2005	12.08	26.26	38.34	7.66	NR	NR	NR	NR	NR	NR
2004	13.41	37.48	50.89	8.16	NR	NR	NR	NR	NR	NR
2003	15.92	42.27	58.19	8.39	NR	NR	NR	NR	NR	NR
2002	15.27	42.36	57.63	7.95	1 610	NR	200	85%	97%	NR
2001	16.81	42.64	59.45	9.78	1 423	NR	210	89%	97%	NR
2000	21.58	25.20	46.78	11.30	NR	NR	NR	NR	NR	NR

Source: Gold Fields (2000-2016)

From its first set of public reports, Sibanye Gold reported the long-term gold price and other modifying factors for the assets that it inherited from Gold Fields, as shown in Table 4.39 to Table 4.42. Following its 2012 inception, Sibanye Gold went on to acquire other assets including the Cooke operation, the West Rand Tailings Retreatment Project, De Bron Merriespruit and Burnstone. The modifying factor reporting for the Mineral Reserves of these assets was relatively less detailed and consistent as shown in Table 4.43 to Table 4.46.

Table 4.39: Sibanye: Total Sibanye Gold Mineral Reserves 2012-2016

SIBANYE GOLD						
Sibanye Gold Total Mineral Reserves						
Year	Proved (Moz)	Probable (Moz)	Total Reserves (Moz)	Reserve Grade (g/t)	Gold Price (USD/oz)	Gold Price (ZAR/kg)
2016	11.94	16.75	28.69	1.10	1 200	490 000
2015	12.45	18.55	30.99	1.10	1 170	430 000
2014	9.00	19.43	28.43	1.00	1 450	420 000
2013	7.99	11.83	19.73	1.20	1 500	410 000
2012	6.69	6.85	13.53	4.72	1 500	380 000

Source: Sibanye Gold (2013-2016)

Table 4.40: Sibanye: Beatrix Mineral Reserves 2012-2016

Beatrix Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	2.05	1.73	3.78	2.90	720	140	171	85%	95%	84%	23%	47%
2015	2.39	1.94	4.33	3.10	840	158	189	84%	96%	88%	19%	70%
2014	1.71	1.96	3.67	3.40	780	172	203	81%	96%	89%	18%	54%
2013	1.84	1.79	3.63	3.00	830	176	201	82%	96%	85%	14%	67%
2012	1.46	1.90	3.36	3.70	970	166	200	77%	96%	NR	NR	NR

Source: Sibanye Gold (2013-2016)

Table 4.41: Sibanye: Driefontein Mineral Reserves 2012-2016

Driefontein Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	4.42	2.51	6.93	5.50	1 230	157	203	87%	97%	81%	29%	53%
2015	4.13	4.06	8.19	6.40	1 330	155	203	86%	97%	81%	31%	56%
2014	2.72	4.64	7.36	5.90	1 280	158	214	86%	97%	86%	35%	59%
2013	2.47	3.59	6.06	5.90	1 340	150	199	80%	97%	85%	33%	113%
2012	1.80	2.57	4.37	5.80	1 460	155	201	80%	97%	80%	NR	NR

Source: Sibanye Gold (2013-2016)

Table 4.42: Sibanye: Kloof Mineral Reserves 2012-2016

Kloof Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	4.70	1.95	6.65	5.30	1 560	159	212	81%	98%	85%	33%	120%
2015	4.86	1.69	6.55	5.70	1 580	161	209	82%	98%	90%	30%	110%
2014	2.93	3.97	6.90	5.90	1 770	160	213	82%	98%	90%	34%	118%
2013	3.60	2.42	6.02	4.90	1 710	156	208	83%	98%	80%	34%	90%
2012	3.42	2.38	5.80	4.80	1 710	157	201	81%	97%	75%	NR	NR

Source: Sibanye Gold (2013-2016)

Table 4.43: Sibanye: Cooke Mineral Reserves 2013-2016

Cooke Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor TSFs (%)	Dilution (%)	Mining Recovery (%)
2016	0.73	0.14	0.87	2.90	980	173	203	83%	96%	58%	17%	18%
2015	1.07	0.46	1.53	3.30	1 090	188	235	79%	95%	60%	25%	34%
2014	1.64	0.31	1.95	2.80	950	160	206	79%	96%	61%	28%	29%
2013	1.15	0.92	2.07	2.00	760	178	238	75%	95%	64%	NR	NR

Source: Sibanye Gold (2013-2016)

Table 4.44: Sibanye: West Rand Tailings Retreatment Project Mineral Reserves 2013-2016

West Rand Tailings Retreatment Project Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	0.00	6.22	6.22	0.30	NR	NR	NR	NR	N/A	53%	N/A	100%
2015	0.00	6.47	6.47	0.30	NR	NR	NR	NR	N/A	52%	N/A	100%
2014	0.00	6.46	6.46	0.28	0.20	NR	NR	NR	N/A	51%	N/A	100%
2013	0.00	4.02	4.02	0.30	NR	NR	NR	NR	N/A	NR	N/A	NR

Source: Sibanye Gold (2013-2016)

Table 4.45: Sibanye: De Bron Merriespruit Mineral Reserves 2013-2016

De Bron Merriespruit Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	0.00	2.11	2.11	4.30	NR	NR	NR	81%	96%	NR	48%	89%
2015	0.00	2.11	2.11	4.30	830	127	187	81%	96%	NR	48%	88%
2014	0.00	2.09	2.09	3.70	780	NR	NR	NR	96%	NR	40%	88%
2013	0.00	3.10	3.10	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Sibanye Gold (2013-2016)

Table 4.46: Sibanye: Burnstone Mineral Reserves 2015-2016

Burnstone Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (cmg/t)	Stoping Width (cm)	Mill Width (cm)	MCF (%)	Plant recovery factor UG (%)	Plant recovery factor SRD (%)	Dilution (%)	Mining Recovery (%)
2016	0.00	2.14	2.14	3.80	400	116	133	88%	96%	NR	14%	102%
2015	0.00	1.80	1.80	4.30	480	120	122	86%	96%	NR	2%	90%

Source: Sibanye Gold (2013-2016)

4.2.2 South African platinum mining company Mineral Reserve reporting quality

South African platinum mining companies have generally undertaken less detailed Mineral Reserve reporting relative to the gold mining companies. South Africa's platinum mining companies are generally not listed on the NYSE and therefore are not exposed to the sometimes more stringent reporting requirements of the SEC. Anglo American Platinum (Amplats), which is one of the world's leading platinum producers, has operations in the Bushveld Complex of South Africa and the Great Dyke of Zimbabwe. The Bushveld Complex hosts the three major reef horizons that Amplats exploits to produce platinum group metals (PGMs), namely; the Merensky Reef, the UG2 Reef and the Platreef. The Main Sulphide Zone (MSZ) is the PGM-bearing reef exploited by Amplats in Zimbabwe's Great Dyke. In 2015, the Amplats operations included the three 100% owned mines of Rustenburg Platinum Mines (RPM) (Thembelani, Bathopele, Khomanani, Khuseleka and Siphumelele) and four joint venture mines (Kroondal, Marikana, BRPM and Pandora) in the western limb of the Bushveld Complex around the town of Rustenburg. Also in the western limb, around the town of Northam, Amplats' operations included the wholly-owned Amandelbult mines (Tumela and Dishaba) and the Union joint venture. In the eastern limb of the Bushveld Complex, Amplats operated the Twickenham Project and had a stake in other joint ventures (Bokoni, Modikwa and Mototolo). In the northern limb of the Bushveld Complex, Amplats operated the Mogalakwena open pit mine and in Zimbabwe Amplats operated the Unki mine (Anglo American Platinum, 2015). In 2016 Amplats sold the bulk of its Rustenburg operations and other related infrastructure to Sibanye Gold (Anglo American Platinum, 2016). Amplats' reporting of its total Mineral Reserves from 2000 to 2016 has not been particularly detailed as the company did not report the long-term PGM price assumptions used in estimating its Mineral Reserves over the entire period, as shown in Table 4.47.

Table 4.47: Amplats: Total Amplats Mineral Reserves 2000-2016

ANGLO AMERICAN PLATINUM									
Anglo American Platinum Total Mineral Reserves									
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Platinum Price (USD/oz)	Palladium Price (USD/oz)	Rhodium Price (USD/oz)	Gold Price (USD/oz)	Exchange Rate (ZAR:USD)
2016	106.60	63.60	170.20	3.00	NR	NR	NR	NR	NR
2015	116.10	68.50	184.60	3.15	NR	NR	NR	NR	NR
2014	114.10	91.00	205.10	3.02	NR	NR	NR	NR	NR
2013	115.60	97.30	212.90	3.06	NR	NR	NR	NR	NR
2012	115.20	62.00	177.20	3.31	NR	NR	NR	NR	NR
2011	114.10	66.80	180.90	3.71	NR	NR	NR	NR	NR
2010	109.40	61.30	170.70	3.73	NR	NR	NR	NR	NR
2009	106.60	69.70	176.30	4.02	NR	NR	NR	NR	NR
2008	108.90	93.30	202.20	4.16	NR	NR	NR	NR	NR
2007	104.90	92.30	197.20	4.15	NR	NR	NR	NR	NR
2006	103.30	92.10	195.40	4.28	NR	NR	NR	NR	NR
2005	83.70	89.10	172.80	4.10	NR	NR	NR	NR	NR
2004	76.30	91.10	167.40	4.36	NR	NR	NR	NR	NR
2003	39.30	124.00	163.30	4.21	NR	NR	NR	NR	NR
2002	32.07	223.48	255.55	4.53	NR	NR	NR	NR	NR
2001	30.40	211.61	242.01	4.71	NR	NR	NR	NR	NR
2000	NR	NR	245.70	4.84	NR	NR	NR	NR	NR

Source: Anglo American Platinum (2000-2016)

Amplats' reporting of its Mineral Reserves has also not been granular, as shown in Table 4.48 to Table 4.51. The company only reported its Mineral Reserves per reef mined and not per operation. Amplats' reporting of technical modifying factors has also been very limited, with only the pay limit range being reported on a consistent basis for the Bushveld Complex reefs (Table 4.48 to Table 4.50) from 2006, and the stoping width range was only reported in 2008 for the Merensky and UG2 Mineral Reserves. None of the modifying factors for the MSZ (Table 4.51) were reported in the period under review.

Table 4.48: Amplats: Merensky Reef Mineral Reserves 2000-2016

Merensky Reef Mineral Reserves								
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)		Stoping Width (cm)	
					From	To	From	To
2016	6.30	1.70	8.00	4.38	4.00	5.60	NR	NR
2015	7.90	3.10	11.00	4.71	2.50	6.20	NR	NR
2014	8.80	2.80	11.60	4.70	2.10	5.30	NR	NR
2013	8.50	2.50	11.00	4.72	2.50	4.80	NR	NR
2012	9.20	3.20	12.40	4.71	2.00	5.60	NR	NR
2011	10.40	8.10	18.50	5.10	1.80	3.70	NR	NR
2010	14.30	8.30	22.60	5.00	2.10	4.40	NR	NR
2009	13.50	14.80	28.30	5.26	2.80	6.10	NR	NR
2008	15.00	21.70	36.70	5.24	2.30	5.70	95	150
2007	14.90	19.20	34.10	5.16	1.30	4.80	NR	NR
2006	17.00	19.70	36.70	5.67	NR	NR	NR	NR
2005	17.20	21.80	39.00	5.57	NR	NR	NR	NR
2004	16.40	24.60	41.00	5.90	NR	NR	NR	NR
2003	12.80	28.90	41.70	6.00	NR	NR	NR	NR
2002	19.29	91.85	111.14	4.42	NR	NR	NR	NR
2001	18.65	98.11	116.76	4.83	NR	NR	NR	NR
2000	NR	NR	118.62	4.86	NR	NR	NR	NR

Source: Anglo American Platinum (2000-2016)

Table 4.49: Amplats: UG2 Reef Mineral Reserves 2000-2016

UG2 Reef Mineral Reserves								
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)		Stoping Width (cm)	
					From	To	From	To
2016	26.30	6.90	33.20	4.15	4.00	5.60	NR	NR
2015	41.60	10.80	52.40	3.99	2.50	6.20	NR	NR
2014	41.80	11.00	52.80	4.00	2.10	5.30	NR	NR
2013	42.00	12.30	54.30	4.15	2.50	4.80	NR	NR
2012	50.80	18.40	69.20	4.15	2.00	5.60	NR	NR
2011	51.50	38.40	89.90	4.36	1.80	3.70	NR	NR
2010	56.70	31.00	87.70	4.33	2.00	3.90	NR	NR
2009	57.60	32.30	89.90	4.37	2.70	5.90	NR	NR
2008	63.40	54.50	117.90	4.30	1.60	4.70	95	150
2007	58.40	57.50	115.90	4.35	1.30	4.40	NR	NR
2006	51.00	56.60	107.60	4.46	2.50	6.20	NR	NR
2005	36.20	55.80	92.00	4.09	NR	NR	NR	NR
2004	30.40	51.30	81.70	4.29	NR	NR	NR	NR
2003	23.20	65.40	88.60	4.38	NR	NR	NR	NR
2002	10.72	128.62	139.34	4.64	NR	NR	NR	NR
2001	9.69	110.49	120.18	4.61	NR	NR	NR	NR
2000	NR	NR	127.00	4.82	NR	NR	NR	NR

Source: Anglo American Platinum (2000-2016)

Table 4.50: Amplats: Platreef Mineral Reserves 2003-2016

Platreef Mineral Reserves*							
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)		Stoping Width (cm)
					From	To	
2016	72.60	51.40	124.00	2.73	1.00	2.70	N/A
2015	65.00	51.10	116.10	2.79	1.00	2.50	N/A
2014	62.20	72.90	135.10	2.67	1.00	2.30	N/A
2013	63.40	78.20	141.60	2.69	1.00	1.70	N/A
2012	53.50	35.60	89.10	2.75	1.00	1.70	N/A
2011	50.40	17.40	67.80	2.90	1.00	1.70	N/A
2010	36.70	18.60	55.30	2.82	1.00	1.70	N/A
2009	34.90	17.50	52.40	3.20	1.70	3.00	N/A
2008	30.00	12.90	42.90	3.27	1.70	3.00	N/A
2007	31.30	12.90	44.20	3.28	1.70	3.00	N/A
2006	35.00	13.10	48.10	3.35	1.70	3.00	N/A
2005	29.70	6.20	35.90	3.21	NR	NR	N/A
2004	27.40	12.10	39.50	3.53	NR	NR	N/A
2003	1.20	26.60	27.80	2.67	NR	NR	N/A

* - Reported as part of Merensky prior to 2003
Source: Anglo American Platinum (2000-2016)

Table 4.51: Amplats: Main Suphide Zone (MSZ) Mineral Reserves 2001-2016

Main Sulphide Zone (MSZ) Mineral Reserves							
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)		Stoping Width (cm)
					From	To	
2016	1.40	3.60	5.00	3.37	NR	NR	NR
2015	1.60	3.50	5.10	3.34	NR	NR	NR
2014	1.30	4.30	5.60	3.54	NR	NR	NR
2013	1.70	4.30	6.00	3.69	NR	NR	NR
2012	1.70	4.80	6.50	3.76	NR	NR	NR
2011	1.80	2.90	4.70	3.79	NR	NR	NR
2010	1.70	3.40	5.10	3.78	NR	NR	NR
2009	0.60	5.10	5.70	3.79	NR	NR	NR
2008	0.50	4.20	4.70	3.79	NR	NR	NR
2007	0.30	2.70	3.00	3.79	NR	NR	NR
2006	0.30	2.70	3.00	3.79	NR	NR	NR
2005	0.60	5.30	5.90	3.81	NR	NR	NR
2004	2.10	3.10	5.20	4.30	NR	NR	NR
2003	2.10	3.10	5.20	4.30	NR	NR	NR
2002	2.06	3.01	5.07	4.30	NR	NR	NR
2001	2.06	3.01	5.07	4.30	NR	NR	NR

Source: Anglo American Platinum (2000-2016)

Northam Platinum Limited's (Northam) Mineral Reserve reporting quality has been more detailed over the period, relative to Amplats. Northam operates the

Zondereinde and Booysendal operations in the western and eastern limb of the Bushveld Complex, respectively. Northam is also party to the Pandora and Dwaalkop joint venture operations. Zondereinde is a deep-level platinum mine which exploits the Merensky and UG2 reefs to a depth of 2,039m below surface through conventional narrow-reef mining methods. Booysendal mine is a shallow mechanised bord and pillar operation exploiting both the Merensky and UG2 reefs. The Mineral Reserves of Booysendal are split between the North and South mines (Northam Platinum, 2016). Northam began reporting the long-term platinum price used in its Mineral Reserves estimations in 2003 and in 2015 it reported the long-term price assumptions for the four major PGMs (4E), followed by reporting of the six major PGMs (6E) price assumptions in 2016, as shown in Table 4.52. The reporting of technical modifying factors by Northam has not been very detailed over the period, between 2000 and 2016. It was only in 2005 and 2006 that Northam reported MCF and other dilution related modifying factors for Zondereinde; besides this no other modifying factors were reported over the period (Table 4.53 to Table 4.57).

Table 4.52: Northam: Total Northam Mineral Reserves 2000-2016

NORTH PLATINUM LIMITED												
Northam Platinum Total Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Platinum Price (USD/oz)	Platinum Price (ZAR/oz)	Palladium Price (USD/oz)	Rhodium Price (USD/oz)	Gold Price (USD/oz)	Ruthenium Price (USD/oz)	Iridium Price (USD/oz)	Exchange Rate (ZAR:USD)
2016	14.10	10.39	24.49	3.43	1 433	20 291	896	1 254	1 209	45	537	14.16
2015	8.13	12.15	20.28	3.68	1 663	19 357	897	1 573	1 325	NR	NR	11.64
2014	6.72	9.55	16.27	3.65	1 495	13 455	NR	NR	NR	NR	NR	9.00
2013	4.50	8.92	13.42	3.75	1 750	15 925	NR	NR	NR	NR	NR	9.10
2012	4.46	9.59	14.05	3.75	1 595	11 963	NR	NR	NR	NR	NR	7.50
2011	4.04	10.13	14.17	3.87	1 838	12 866	NR	NR	NR	NR	NR	7.00
2010	3.94	9.52	13.46	4.19	1 545	12 360	NR	NR	NR	NR	NR	8.00
2009	0.95	7.20	8.15	4.80	1 050	9 450	NR	NR	NR	NR	NR	9.00
2008	0.76	8.41	9.17	4.60	1 845	14 391	NR	NR	NR	NR	NR	7.80
2007	0.78	10.14	10.92	4.74	920	6 670	NR	NR	NR	NR	NR	7.25
2006	0.79	9.13	9.92	4.92	900	5 850	NR	NR	NR	NR	NR	6.50
2005	0.65	12.05	12.70	4.82	750	4 950	NR	NR	NR	NR	NR	6.60
2004	0.63	9.94	10.57	4.95	630	4 347	NR	NR	NR	NR	NR	6.90
2003	0.91	10.38	11.29	4.77	661	5 004	NR	NR	NR	NR	NR	7.57
2002	0.73	10.50	11.23	5.10	NR	NR	NR	NR	NR	NR	NR	NR
2001	0.54	9.09	9.63	5.00	NR	NR	NR	NR	NR	NR	NR	NR
2000	0.64	9.10	9.74	5.32	NR	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Table 4.53: Northam: Zondereinde Mine Mineral Reserves 2000-2016

Zondereinde Mine Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping (%)	Other Sources (%)	Development (%)	Survey Discrepancy (%)	MCF (%)	Block/dilution Factor (%)
2016	2.11	9.61	11.72	4.58	NR	NR	NR	NR	NR	NR	NR
2015	1.50	9.10	10.60	4.51	NR	NR	NR	NR	NR	NR	NR
2014	1.30	6.49	7.79	4.55	NR	NR	NR	NR	NR	NR	NR
2013	1.32	5.91	7.23	4.78	NR	NR	NR	NR	NR	NR	NR
2012	1.12	6.61	7.73	4.74	NR	NR	NR	NR	NR	NR	NR
2011	1.00	7.15	8.15	4.84	NR	NR	NR	NR	NR	NR	NR
2010	0.94	6.59	7.53	4.99	NR	NR	NR	NR	NR	NR	NR
2009	0.94	7.20	8.14	4.80	NR	NR	NR	NR	NR	NR	NR
2008	0.76	8.41	9.17	4.60	NR	NR	NR	NR	NR	NR	NR
2007	0.78	10.14	10.92	4.74	NR	NR	NR	NR	NR	NR	NR
2006	0.79	9.13	9.92	4.92	NR	91%	4%	4%	2%	95%	98%
2005	0.65	12.05	12.70	4.82	NR	91%	4%	4%	1%	94%	100%
2004	0.63	9.94	10.57	4.95	NR	NR	NR	NR	NR	NR	NR
2003	0.91	10.38	11.29	4.77	NR	NR	NR	NR	NR	NR	NR
2002	0.73	10.50	11.23	5.10	NR	NR	NR	NR	NR	NR	NR
2001	0.54	9.09	9.63	5.00	NR	NR	NR	NR	NR	NR	NR
2000	0.64	9.10	9.74	5.32	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Table 4.54: Northam: Booysendal North Mine Mineral Reserves 2010-2016

Booysendal North Mine Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping (%)	Other Sources (%)	Development (%)	Survey Discrepancy (%)	MCF (%)	Block/dilution Factor (%)
2016	5.36	0.00	5.36	2.98	NR	NR	NR	NR	NR	NR	NR
2015	5.53	0.00	5.53	2.98	NR	NR	NR	NR	NR	NR	NR
2014	4.32	0.00	4.32	3.00	NR	NR	NR	NR	NR	NR	NR
2013	3.17	0.00	3.17	2.96	NR	NR	NR	NR	NR	NR	NR
2012	3.33	0.00	3.33	2.95	NR	NR	NR	NR	NR	NR	NR
2011	3.03	0.00	3.03	3.08	NR	NR	NR	NR	NR	NR	NR
2010	2.99	0.00	2.99	2.99	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Table 4.55: Northam: Booysendal South Mine Mineral Reserves 2016

Booysendal South Mine Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping (%)	Other Sources (%)	Development (%)	Survey Discrepancy (%)	MCF (%)	Block/dilution Factor (%)
2016	6.61	0.64	7.25	2.65	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Table 4.56: Northam: Pandora Mineral Reserves 2009-2016

Pandora Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping (%)	Other Sources (%)	Development (%)	Survey Discrepancy (%)	MCF (%)	Block/dilution Factor (%)
2016	0.02	0.14	0.16	4.10	NR	NR	NR	NR	NR	NR	NR
2015	0.01	0.16	0.17	4.11	NR	NR	NR	NR	NR	NR	NR
2014	0.01	0.17	0.18	4.11	NR	NR	NR	NR	NR	NR	NR
2013	0.01	0.16	0.17	4.02	NR	NR	NR	NR	NR	NR	NR
2012	0.01	0.13	0.14	4.14	NR	NR	NR	NR	NR	NR	NR
2011	0.01	0.13	0.14	3.99	NR	NR	NR	NR	NR	NR	NR
2010	0.01	0.08	0.09	4.25	NR	NR	NR	NR	NR	NR	NR
2009	0.01	0.00	0.01	4.28	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Table 4.57: Northam: Dwaalkop Mineral Reserves 2010-2015

Dwaalkop Mineral Reserves											
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping (%)	Other Sources (%)	Development (%)	Survey Discrepancy (%)	MCF (%)	Block/dilution Factor (%)
2015	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR
2014	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR
2013	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR
2012	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR
2011	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR
2010	0.00	2.85	2.85	2.98	NR	NR	NR	NR	NR	NR	NR

Source: Northam Platinum (2000-2016)

Lonmin plc (Lonmin) has had the most detailed Mineral Reserve reporting of the major South African platinum mining companies assessed. Lonmin owns and operates the Marikana operations, which exploit the Meresnky and UG2 reefs to an average depth of 500m through a combination of vertical and decline shafts. Mining at Marikana is mostly in the form conventional stoping methods, with a smaller portion of the mining being conducted by mechanised/hybrid methods (Lonmin, 2016). The Pandora joint venture is the other Lonmin operation, where mining is done through a single incline shaft to access the UG2 reef using conventional breast mining. Lonmin's Limpopo operations consist of the Baobab, Dwaalkop, Doornvlei and Baobab East project areas. The Baobab mine was placed on care and maintenance in January 2010 and the Mineral Reserves removed in 2015 (Lonmin, 2016). Lonmin has consistently reported the long-term price assumptions for the 6 major PGMs (6E) for Mineral Reserve estimates from 2005, as shown in Table 4.58. Lonmin also reported the dilution, mining losses and depth cut-off modifying factors for its Mineral Reserve estimates on a consistent basis from 2007, as shown in Table 4.59 to Table 4.62.

Table 4.58: Lonmin: Total Lonmin Mineral Reserves 2000-2016

LONMIN PLC												
Lonmin Total Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Platinum Price (USD/oz)	Platinum Price (ZAR/oz)	Palladium Price (USD/oz)	Rhodium Price (USD/oz)	Gold Price (USD/oz)	Ruthenium Price (USD/oz)	Iridium Price (USD/oz)	Exchange Rate (ZAR:USD)
2016	2.30	29.40	31.70	3.82	1 622	20 729	889	2 369	1 191	86	521	12.78
2015	2.50	33.80	36.30	3.88	1 536	18 632	842	2 244	1 128	82	494	12.13
2014	2.14	40.18	42.32	3.70	1 865	16 785	888	1 348	1 385	95	630	9.00
2013	2.04	40.78	42.82	3.70	1 865	16 785	888	1 348	1 385	95	630	9.00
2012	1.64	39.68	41.32	3.92	1 750	14 875	870	1 500	1 500	205	610	8.50
2011	1.39	42.00	43.39	3.95	1 900	15 200	850	2 500	1 500	200	600	8.00
2010	1.37	44.51	45.88	4.07	1 800	14 904	500	3 000	800	200	450	8.28
2009	1.18	43.66	44.84	3.98	1 600	14 400	400	3 000	700	150	430	9.00
2008	1.10	47.28	48.38	3.93	1 500	12 000	500	3 000	550	450	410	8.00
2007	1.68	49.61	51.29	4.03	1 270	9 208	350	4 000	680	530	410	7.25
2006	3.06	54.24	57.30	4.11	1 100	7 700	300	3 500	600	65	150	7.00
2005	2.39	57.13	59.52	4.26	760	4 940	160	1 125	380	60	135	6.50
2004	2.10	61.10	63.20	4.02	NR	NR	NR	NR	NR	NR	NR	NR
2003	2.76	73.02	75.78	NR	NR	NR	NR	NR	NR	NR	NR	NR
2002	2.61	74.19	76.80	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	2.70	77.70	80.40	NR	NR	NR	NR	NR	NR	NR	NR	NR
2000	2.60	78.70	81.30	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Lonmin (2000-2016)

Table 4.59: Lonmin: Marikana Mineral Reserves 2000-2016

Marikana Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping Width (cm)	Dilution (%)	Losses (%)	Depth Cut-Off (m)	MCF (%)
2016	2.20	28.00	30.20	4.06	NR	NR	21%	20%	1 400	NR
2015	2.40	32.30	34.70	4.10	NR	NR	21%	20%	1 400	NR
2014	2.00	33.50	35.50	3.98	NR	NR	21%	20%	1 400	NR
2013	1.90	34.10	36.00	3.98	NR	NR	21%	20%	1 400	NR
2012	1.50	33.70	35.20	4.06	NR	NR	21%	20%	1 400	NR
2011	1.30	36.10	37.40	4.09	NR	NR	20%	17%	1 400	NR
2010	1.30	38.60	39.90	4.22	NR	NR	19%	15%	1 400	NR
2009	1.10	38.20	39.30	4.11	NR	NR	17%	17%	1 400	NR
2008	1.00	42.20	43.20	4.03	NR	NR	21%	16%	1 400	NR
2007	1.60	42.90	44.50	4.18	NR	NR	26%	18%	1 400	NR
2006	1.96	52.46	54.42	4.14	NR	NR	NR	NR	1 400	NR
2005	2.07	53.36	55.43	4.31	NR	NR	NR	NR	1 400	NR
2004	2.10	61.10	63.20	4.02	NR	NR	NR	NR	NR	NR
2003	2.76	73.02	75.78	NR	NR	NR	NR	NR	NR	NR
2002	2.61	74.19	76.80	NR	NR	NR	NR	NR	NR	NR
2001	2.70	77.70	80.40	NR	NR	NR	NR	NR	NR	NR
2000	2.60	78.70	81.30	NR	NR	NR	NR	NR	NR	NR

Source: Lonmin (2000-2016)

Table 4.60: Lonmin: Pandora Mineral Reserves 2007-2016

Pandora Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping Width (cm)	Dilution (%)	Losses (%)	Depth Cut-Off (m)	MCF (%)
2016	0.10	0.70	0.80	4.20	NR	NR	14%	18%	600	NR
2015	0.10	0.80	0.90	4.09	NR	NR	14%	18%	600	NR
2014	0.10	0.70	0.80	4.11	NR	NR	14%	18%	600	NR
2013	0.10	0.70	0.80	4.11	NR	NR	14%	18%	600	NR
2012	0.10	0.70	0.80	4.02	NR	NR	14%	20%	600	NR
2011	0.05	0.62	0.67	4.14	NR	NR	13%	18%	600	NR
2010	0.03	0.63	0.66	3.98	NR	NR	14%	18%	600	NR
2009	0.04	0.38	0.42	4.25	NR	NR	13%	18%	600	NR
2008	0.06	0.00	0.06	4.28	NR	NR	15%	17%	600	NR
2007	0.04	0.00	0.04	4.55	NR	NR	10%	14%	600	NR

Source: Lonmin (2000-2016)

Table 4.61: Lonmin: Tailings Dam Mineral Reserves 2013-2016

Tailings Dams Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping Width (cm)	Dilution (%)	Losses (%)	Depth Cut-Off (m)	MCF (%)
2016	0.00	0.70	0.70	1.10	NR	N/A	N/A	N/A	N/A	NR
2015	0.00	0.70	0.70	1.10	NR	N/A	N/A	N/A	N/A	NR
2014	0.00	0.70	0.70	1.10	NR	N/A	N/A	N/A	N/A	NR
2013	0.00	0.70	0.70	1.10	NR	N/A	N/A	N/A	N/A	NR

Source: Lonmin (2000-2016)

Table 4.62: Lonmin: Limpopo Mineral Reserves 2005-2016

Limpopo Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (g/t)	Stoping Width (cm)	Dilution (%)	Losses (%)	Depth Cut-Off (m)	MCF (%)
2014	0.04	5.28	5.32	3.20	NR	NR	13%	16%	750	NR
2013	0.04	5.28	5.32	3.20	NR	NR	13%	16%	750	NR
2012	0.04	5.28	5.32	3.20	NR	NR	13%	16%	750	NR
2011	0.04	5.28	5.32	4.20	NR	NR	13%	16%	750	NR
2010	0.04	5.28	5.32	4.20	NR	NR	13%	16%	750	NR
2009	0.04	5.08	5.12	3.22	NR	NR	13%	16%	750	NR
2008	0.04	5.08	5.12	3.22	NR	NR	13%	16%	750	NR
2007	0.04	6.71	6.75	3.26	NR	NR	11%	17%	1 000	NR
2006	1.10	1.78	2.88	3.57	NR	NR	NR	NR	1 000	NR
2005	0.32	3.77	4.09	3.71	NR	NR	NR	NR	1 000	NR

Source: Lonmin (2000-2016)

Impala Platinum Holdings Limited (Implats) operates 5 main operations (Impala, Zimplats, Marula, Mimosa and Two Rivers) consisting of 21 underground shafts across South Africa's Bushveld Complex and Zimbabwe's Great Dyke (Implats, 2016). Impala consists of 13 underground shafts that mostly exploit the Merensky and UG2 reefs around the town of Rustenburg. The Impala operations mostly make use of conventional breast mining, with the exception of 14 Shaft, which uses mechanised bord and pillar mining in selected areas of the Merensky reef. The Marula operations are located in the eastern limb of the Bushveld Complex, some 35 km from the town of Burgersfort. Only the UG2 reef is exploited at Marula, with access to the orebody being via two decline shaft systems and using both conventional and hybrid mining methods. The Two Rivers mine, also located near Burgersfort, exploits the UG2 reef through mechanised bord and pillar mining methods, with orebody access being provided by a two-shaft system. Zimplats operates the Ngezi mine, located about 150km from the Harare, and Hartley mine which is 77km north of Ngezi mine. The Zimplats operations exploit the MSZ via four portals and an open pit. The underground portals make use of mechanised bord and pillar mining methods. Mimosa is located about 150km from Bulawayo and exploits the MSZ through a single decline shaft, and bord and pillar mining methods (Implats, 2016). Implats began reporting the long-term platinum price used in its Mineral Reserve estimates in 2003. Implats introduced the reporting of the long-term prices for palladium and rhodium in 2012, followed by the reporting on a 6E PGM basis in 2015, as shown in Table 4.63. In 2015, Implats also began reporting the long-term basket price, making it the only major South African platinum mining company to have reported on the long-term basket price used in its Mineral Reserve estimates between 2000 and 2016. Implats' reporting of the other modifying factors has been relatively inadequate, with Implats only introducing the reporting of ranges for the modifying factors in 2016, as shown in Table 4.64 to Table 4.70. The granularity of Implats' reporting has also been insufficient, as demonstrated by the fact that the Mineral Reserves for the 13 Impala shafts have been reported on a consolidated basis between 2000 to 2016 (Table 4.64).

Table 4.63: Implats: Total Implats Mineral Reserves 2000-2016

IMPALA PLATINUM													
Impala Platinum Total Mineral Reserves													
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)*	Platinum Price (USD/oz)	Platinum Price (ZAR/oz)	Palladium Price (USD/oz)	Rhodium Price (USD/oz)	Gold Price (USD/oz	Ruthenium Price (USD/oz)	Iridium Price (USD/oz)	Basket Price (ZAR/oz)	Exchange Rate (ZAR:USD)
2016	12.30	31.70	44.00	3.67	1 260	18 648	815	1 045	1 080	36	460	29 276	14.80
2015	9.50	44.30	53.80	3.81	1 568	17 718	1 066	1 540	1 237	59	571	23 889	11.30
2014	11.74	44.20	55.94	3.75	2 000	26 760	1 200	1 700	NR	NR	NR	NR	13.38
2013	13.60	53.90	67.50	3.69	2 017	18 778	1 156	1 728	NR	NR	NR	NR	9.31
2012	13.80	55.00	68.80	3.73	2 010	16 080	1 108	1 740	NR	NR	NR	NR	8.00
2011	12.90	57.70	70.60	3.63	NR	22 560	NR	NR	NR	NR	NR	NR	NR
2010	11.70	61.00	72.70	3.66	NR	27 716	NR	NR	NR	NR	NR	NR	NR
2009	13.62	59.80	73.42	3.68	NR	20 879	NR	NR	NR	NR	NR	NR	NR
2008	15.90	67.10	83.00	3.70	NR	24 083	NR	NR	NR	NR	NR	NR	NR
2007	15.60	63.20	78.80	3.70	NR	11 085	NR	NR	NR	NR	NR	NR	NR
2006	23.70	60.30	84.00	NR	NR	7 850	NR	NR	NR	NR	NR	NR	NR
2005	22.80	63.30	86.10	NR	NR	6 700	NR	NR	NR	NR	NR	NR	NR
2004	12.80	67.60	80.40	NR	NR	6 100	NR	NR	NR	NR	NR	NR	NR
2003	11.80	64.60	76.40	NR	NR	6 100	NR	NR	NR	NR	NR	NR	NR
2002	6.80	41.40	48.20	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	6.60	35.80	42.40	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2000	5.60	37.50	43.10	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

* - Combination of 6E and 4E reporting from 2000 to 2006
Source: Impala Platinum Holdings (2000-2016)

Table 4.64: Implats: Impala Mineral Reserves 2000-2016

Impala Mineral Reserves																
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)*	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2016	3.40	19.80	23.20	3.94	NR	20%	40%	8%	10%	9%	12%	88%	92%	109	126	87%	88%
2015	3.10	30.00	33.10	4.02	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2014	3.10	29.60	32.70	3.95	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2013	2.80	29.70	32.50	4.02	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2012	3.50	30.80	34.30	4.05	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2011	3.30	32.40	35.70	4.02	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2010	3.70	32.40	36.10	3.87	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2009	4.90	32.00	36.90	3.83	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2008	5.40	33.10	38.50	3.89	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	5.90	26.70	32.60	3.96	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2006	7.70	33.70	41.40	4.88	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2005	7.30	35.20	42.50	4.96	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2004	6.20	28.00	34.20	5.07	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2003	6.70	26.00	32.70	5.07	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2002	6.70	33.70	40.40	5.09	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	6.40	34.50	40.90	4.96	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2000	5.60	37.50	43.10	4.97	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

* - 6E reporting prior to 2007
Source: Impala Platinum Holdings (2000-2016)

Table 4.65: Implats: Marula Mineral Reserves 2002-2016

Marula Mineral Reserves																
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)*	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2016	0.60	2.80	3.40	3.97	NR	15%	35%	8%	12%	9%	12%	96%	98%	132	132	87%	88%
2015	0.40	3.30	3.70	3.87	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2014	0.40	2.90	3.30	4.14	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2013	0.40	3.00	3.40	4.05	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2012	0.30	3.10	3.40	4.04	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2011	0.30	3.30	3.60	3.99	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2010	0.00	6.00	6.00	4.10	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2009	0.00	5.20	5.20	4.48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2008	0.00	5.40	5.40	4.45	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	0.00	5.60	5.60	4.42	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2006	6.90	0.00	6.90	5.20	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2005	7.00	0.00	7.00	5.16	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2004	0.00	6.30	6.30	4.76	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2003	0.00	5.80	5.80	3.55	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2002	0.00	6.40	6.40	3.68	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

* - 6E reporting prior to 2007
Source: Impala Platinum Holdings (2000-2016)

Table 4.66: Implats: Two Rivers Mineral Reserves 2005-2016

Two Rivers Mineral Reserves																	
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2016	0.60	1.40	2.00	2.93	NR	22%	32%	25%	35%	26%	30%	95%	99%	246	278	86%	88%
2015	1.20	2.90	4.10	3.01	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2014	1.14	1.90	3.04	3.06	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2013	1.10	2.20	3.30	2.95	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2012	0.80	2.50	3.30	2.93	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2011	1.00	2.70	3.70	2.95	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2010	0.50	2.90	3.40	2.94	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2009	0.92	2.80	3.72	3.23	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2008	1.30	3.00	4.30	3.33	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	1.30	3.20	4.50	3.44	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2006	1.20	3.30	4.50	3.48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2005	1.20	3.30	4.50	3.48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Impala Platinum Holdings (2000-2016)

Table 4.67: Implats: Zimplats Mineral Reserves 2003-2016

Zimplats Mineral Reserves																	
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2016	5.50	6.40	11.90	3.31	NR	5%	26%	20%	34%	6%	10%	91%	91%	275	275	80%	81%
2015	2.20	6.80	9.00	3.36	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2014	5.90	8.50	14.40	3.37	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2013	7.60	17.80	25.40	3.33	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2012	7.20	17.30	24.50	3.35	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2011	6.10	18.00	24.10	3.40	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2010	5.70	17.90	23.60	3.43	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2009	5.90	18.00	23.90	3.43	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2008	7.10	17.90	25.00	3.41	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	6.10	20.00	26.10	3.36	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2006	5.70	21.60	27.30	3.35	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2005	5.40	23.00	28.40	3.31	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2004	4.70	31.80	36.50	3.34	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2003	5.00	31.90	36.90	3.33	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Impala Platinum Holdings (2000-2016)

Table 4.68: Implats: Mimosa Mineral Reserves 2003-2016

Mimosa Mineral Reserves																	
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2016	2.20	1.30	3.50	3.59	NR	11%	26%	22%	28%	8%	12%	92%	96%	200	200	78%	80%
2015	2.60	1.30	3.90	3.59	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2014	1.20	1.30	2.50	3.37	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2013	1.70	1.20	2.90	3.40	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2012	2.00	1.30	3.30	3.51	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2011	2.20	1.30	3.50	3.51	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2010	1.80	1.80	3.60	3.42	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2009	1.90	1.80	3.70	3.50	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2008	2.10	1.80	3.90	3.48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	2.30	1.80	4.10	3.52	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2006	2.20	1.70	3.90	3.62	NR	NR	NR	NR	NR	NR	NR	NR	NR	180	195	NR	NR
2005	1.90	1.80	3.70	3.65	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2004	1.90	1.50	3.40	3.64	NR	NR	NR	NR	NR	NR	NR	NR	NR	180	180	NR	NR
2003	0.10	0.90	1.00	3.79	NR	NR	NR	15%	15%	NR	NR	NR	NR	180	180	NR	NR

Source: Impala Platinum Holdings (2000-2016)

Table 4.69: Implats: Afplats-Leeuwkop Mineral Reserves 2007-2008

Afplats - Leeuwkop Mineral Reserves																	
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2008	0.00	5.90	5.90	3.75	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2007	0.00	5.90	5.90	3.75	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Impala Platinum Holdings (2000-2016)

Table 4.70: Implats: Crocodile River Mineral Reserves 2000-2001

Crocodile River Mineral Reserves																	
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Paylimit (cm.g/t)	Geological Losses (%)		Pillar Factors (%)		Resource Dilution (%)		Mine Call Factors (%)		Stoping Width (cm)		Concentrator Recoveries (%)	
						From	To	From	To	From	To	From	To	From	To	From	To
2002	0.10	1.30	1.40	4.45	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	0.20	1.30	1.50	4.88	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Source: Impala Platinum Holdings (2000-2016)

Following its acquisition of Amplats' RPM assets in 2016, Sibanye has reported the Mineral Reserves along with the 4E PGM long-term price used in the estimation process, although Amplats had never reported long-term prices for these assets (Table 4.71). Sibanye also reported the other modifying factors in detail for the RPM assets and the assets it acquired from Aquarius Platinum, as shown in Table 4.71 to Table 4.74, which has not always been the custom of the traditional South African platinum mining companies.

Table 4.71: Sibanye: Total Sibanye Platinum Mineral Reserves 2015-2016

SIBANYE PLATINUM								
Sibanye Platinum Total Mineral Reserves								
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (4E g/t)	Platinum Price (ZAR/oz)	Palladium Price (ZAR/oz)	Rhodium Price (ZAR/oz)	Gold Price (ZAR/oz)
2016	18.02	5.17	23.19	2.76	15 500	9 100	10 000	15 200
2015	26.62	9.09	35.70	NR	NR	NR	NR	NR

Source: Sibanye (2016)

Table 4.72: Sibanye: Rustenburg Mineral Reserves 2015-2016

Rustenburg Mineral Reserves							
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Mined Value (g/t)	MCF (%)	Stoping Width (cm)
2016	15.17	4.04	19.21	2.71	3.67	96.7%	146
2015	21.28	7.48	28.76	NR	3.79	93.9%	144

Source: Sibanye (2016)

Table 4.73: Sibanye: Kroondal Mineral Reserves 2015-2016

Kroondal Mineral Reserves												
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Geological Loss (%)	Extraction (%)	Off-Reef (%)	Re-development (%)	Sliping (%)	Scalping (%)	Scalping Grade (g/t)	Mining Loss (%)
2016	1.80	0.49	2.29	2.66	0.29	86%	2.4%	11.2%	2.2%	5.4%	0.64	2.2%
2015	2.94	0.91	3.85	NR	0.26	86%	2.8%	10.8%	2.2%	5.5%	0.64	2.6%

Source: Sibanye (2016)

Table 4.74: Sibanye: Mimosa Mineral Reserves 2015-2016

Mimosa Mineral Reserves										
Year	Proved (Moz)	Probable (Moz)	Total Reserve (Moz)	Reserve Grade (g/t)	Paylimit (g/t)	Mined Value (g/t)	Mining Dilution (%)	MCF (%)	Stoping Width (cm)	Plant Recovery for UG (%)
2016	1.05	0.64	1.69	3.60	2.95	3.57	3.0%	91.9%	2.06	98.5%
2015	1.31	0.65	1.96	NR	2.36	3.65	3.0%	93.1%	2.07	99.3%

Source: Sibanye (2016)

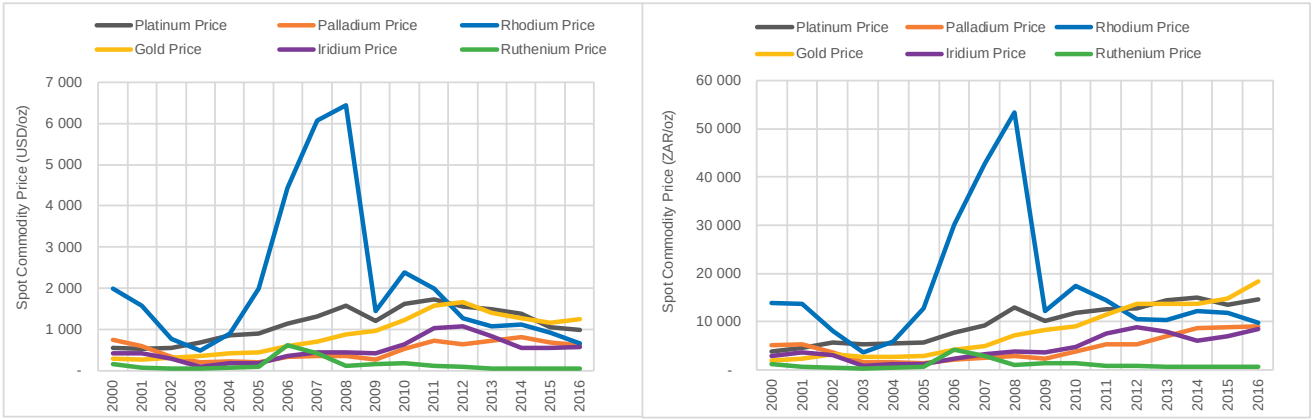
4.3 The commodity price assumptions of South African gold and platinum mining companies relative to historical spot prices

Commodity prices are commonly subject to variability due to factors that are often related to supply and demand dynamics. In the case of gold and PGMs, the period from 2000 to 2008 was marked by a general upward trend in the prices of these precious metals. However following the 2007/2008 Global Financial Crisis, precious metal prices that had reached peak levels crashed rapidly in 2009, followed by marginal recoveries in 2010 to 2012, thereafter continuing to experience downward trends in US dollar terms, as shown in Table 4.75 and Figure 4.1. While US dollar denominated gold and PGM prices have shown a general downward from 2012 to 2016, South African Rand (ZAR) denominated commodity prices have shown a general positive trend from 2000 to 2016 due to the generally depreciating value of the Rand against the US dollar in periods of weak US dollar prices. South African gold and platinum mining companies have therefore made their long-term commodity price assumptions in an increasing Rand-price environment between 2000 and 2016.

Table 4.75: Historical gold and PGM prices 2000-2016

Year	Gold Price (USD/oz)	Platinum Price (USD/oz)	Palladium Price (USD/oz)	Rhodium Price (USD/oz)	Iridium Price (USD/oz)	Ruthenium Price (USD/oz)	Gold Price (ZAR/oz)	Platinum Price (ZAR/oz)	Palladium Price (ZAR/oz)	Rhodium Price (ZAR/oz)	Iridium Price (ZAR/oz)	Ruthenium Price (ZAR/oz)
2016	1 249	987	613	663	575	40	18 367	14 525	9 020	9 750	8 460	588
2015	1 160	1 052	692	919	544	42	14 798	13 421	8 826	11 731	6 936	536
2014	1 266	1 384	803	1 128	556	58	13 731	15 009	8 710	12 237	6 027	629
2013	1 411	1 485	725	1 075	826	57	13 618	14 339	7 002	10 377	7 975	550
2012	1 669	1 549	644	1 270	1 070	90	13 699	12 720	5 290	10 425	8 786	739
2011	1 572	1 719	733	1 990	1 036	110	11 417	12 488	5 328	14 455	7 527	799
2010	1 226	1 611	526	2 384	642	180	8 977	11 792	3 854	17 451	4 702	1 318
2009	973	1 205	264	1 442	425	160	8 249	10 211	2 235	12 218	3 605	1 356
2008	872	1 571	352	6 455	450	110	7 203	12 980	2 909	53 321	3 718	909
2007	697	1 305	355	6 076	447	415	4 909	9 192	2 499	42 805	3 149	2 924
2006	604	1 142	321	4 442	350	610	4 093	7 733	2 172	30 086	2 368	4 131
2005	445	897	202	2 002	169	87	2 832	5 705	1 282	12 732	1 078	553
2004	410	846	230	904	186	68	2 648	5 464	1 485	5 839	1 204	439
2003	364	692	199	475	93	41	2 753	5 233	1 508	3 596	704	310
2002	310	540	337	768	294	40	3 272	5 688	3 548	8 095	3 095	422
2001	271	529	604	1 582	413	80	2 334	4 557	5 199	13 623	3 556	689
2000	279	545	743	1 993	415	160	1 937	3 780	5 155	13 832	2 880	1 110

Sources: SNL Metals & Mining, Kitco, Metalary and Quandl.



Sources: SNL Metals & Mining, Kitco, Metalary and Quandl.

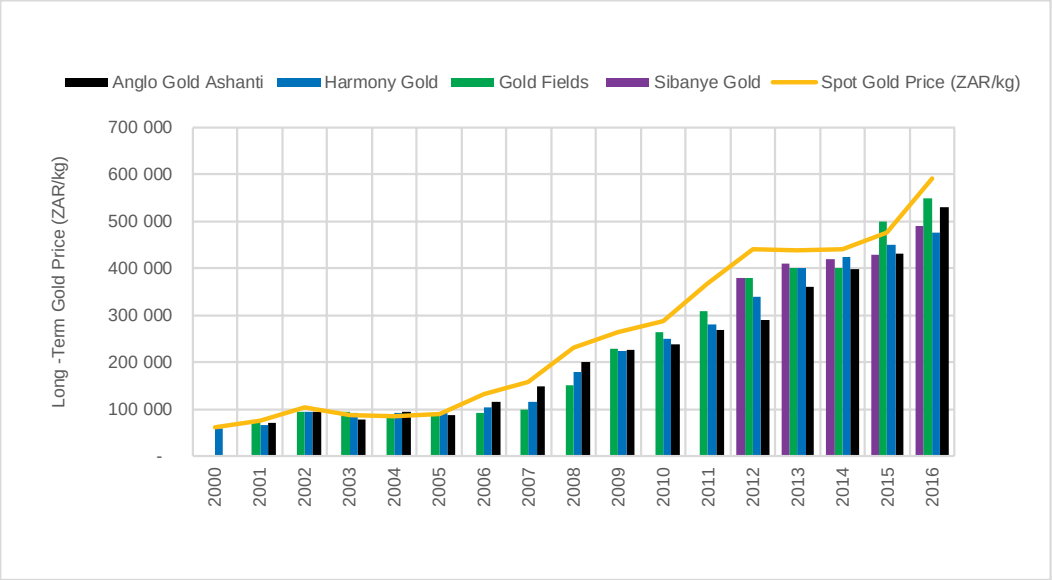
Figure 4.1: Historical gold and PGM spot prices 2000-2016

South Africa's major gold mining companies have a relatively good track record of reporting the long-term gold price use in their Mineral Reserve declarations. Table 4.76 shows that by 2001, a year after the introduction of the SAMREC Code, the three major South African gold producers were reporting their long-term gold price assumptions. Table 4.76 and Figure 4.2 also show that between 2000 and 2016, South African gold mining companies assumed long-term gold prices, in ZAR/kg nominal terms, that were consistently either lower than or in line with prevailing spot prices. This suggests that South African gold mining companies had a lower probability of reporting unprofitable ounces as part of their Mineral Reserves.

Table 4.76: Historical spot gold prices and long-term gold price assumptions 2000-2016

Year	Spot Gold Price (ZAR/kg)	Long-Term Gold Price Assumptions (ZAR/kg)			
		Anglo Gold Ashanti	Harmony Gold	Gold Fields	Sibanye Gold
2016	590 506	530 000	475 107	550 000	490 000
2015	475 767	431 000	450 026	500 000	430 000
2014	441 465	398 452	425 064	400 000	420 000
2013	437 828	360 252	400 148	400 000	410 000
2012	440 417	290 064	339 833	380 000	380 000
2011	367 051	269 841	279 888	310 000	N/A
2010	288 628	238 028	250 149	265 000	N/A
2009	265 204	227 627	224 975	230 000	N/A
2008	231 573	200 698	179 883	150 000	N/A
2007	157 820	148 536	115 022	100 000	N/A
2006	131 587	114 939	104 972	92 000	N/A
2005	91 065	86 807	91 996	92 000	N/A
2004	85 121	94 764	91 996	90 000	N/A
2003	88 522	78 769	92 948	95 000	N/A
2002	105 194	94 041	94 845	95 111	N/A
2001	75 056	71 262	67 388	69 992	N/A
2000	62 279	NR	60 033	NR	N/A

Sources: SNL Metals & Mining, Anglo Gold Ashanti (2000-2016), Harmony Gold (2000-2016), Gold Fields (2000-2016) and Sibanye Gold (2013-2016).



Sources: SNL Metals & Mining, Anglo Gold Ashanti (2000-2016), Harmony Gold (2000-2016), Gold Fields (2000-2016) and Sibanye Gold (2013-2016).

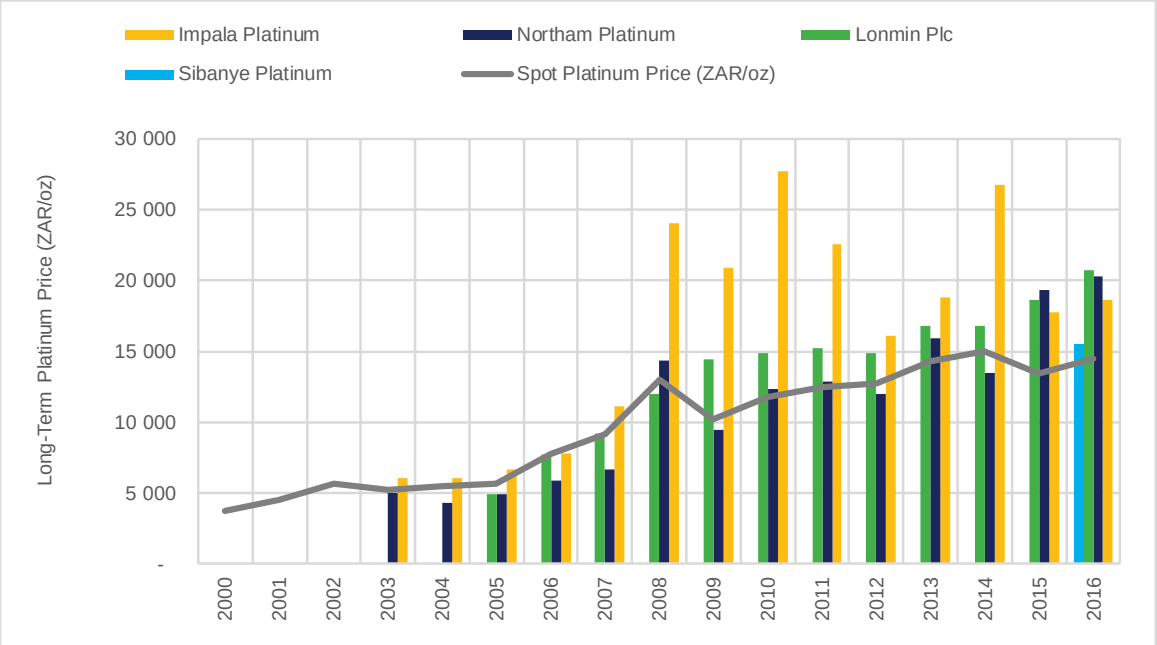
Figure 4.2: Long-term gold price assumptions relative to spot prices 2000-2016

The track record of South African platinum mining companies for reporting their long-term platinum prices for Mineral Reserve declaration between 2000 and 2016 has not been as good as that of the gold mining companies. Implats and Northam only began reporting their long-term platinum prices in 2003, followed by Lonmin which began reporting its long-term platinum prices in 2005; while Amplats has never reported its long-term prices, as shown in Table 4.77. Figure 4.3 and Table 4.77 show that between 2003 and 2016, South African platinum mining companies have generally reported long-term platinum prices that were higher than prevailing spot prices. Implats' long-term platinum prices have often been the most bullish throughout the period under review, while Northam's long-term prices have been relatively conservative. Figure 4.4 shows that for the other PGMs, South African platinum mining companies have generally reported prices higher than spot prices for palladium between 2000 and 2016 and more optimistic prices for rhodium between 2009 and 2016. However, for gold and iridium, South African platinum mining companies have generally reported long-term prices that were more conservative than spot prices. The reporting trends of South African platinum mining companies suggests that between 2000 and 2016, they were more likely to report uneconomic ounces as part of their Mineral Reserves, when compared to gold mining companies.

Table 4.77: Historical spot platinum prices and long-term gold price assumptions 2000-2016

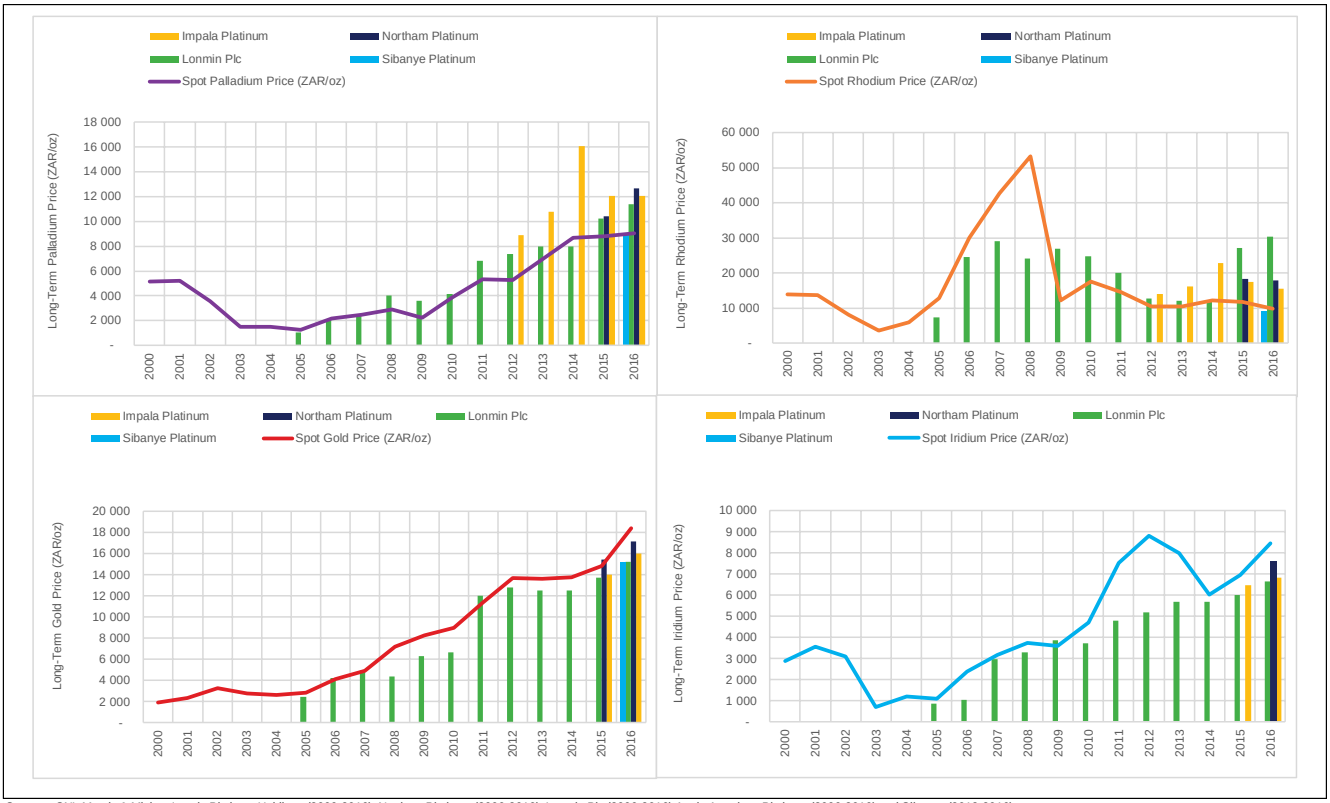
Year	Spot Platinum Price (ZAR/oz)	Long-Term-Platinum Price Assumptions (ZAR/oz)				
		Impala Platinum Holdings Limited	Northam Platinum	Lonmin Plc	Anglo American Platinum	Sibanye Platinum
2016	14 525	18 648	20 291	20 729	NR	15 500
2015	13 421	17 718	19 357	18 632	NR	N/A
2014	15 009	26 760	13 455	16 785	NR	N/A
2013	14 339	18 778	15 925	16 785	NR	N/A
2012	12 720	16 080	11 963	14 875	NR	N/A
2011	12 488	22 560	12 866	15 200	NR	N/A
2010	11 792	27 716	12 360	14 904	NR	N/A
2009	10 211	20 879	9 450	14 400	NR	N/A
2008	12 980	24 083	14 391	12 000	NR	N/A
2007	9 192	11 085	6 670	9 208	NR	N/A
2006	7 733	7 850	5 850	7 700	NR	N/A
2005	5 705	6 700	4 950	4 940	NR	N/A
2004	5 464	6 100	4 347	NR	NR	N/A
2003	5 233	6 100	5 004	NR	NR	N/A
2002	5 688	NR	NR	NR	NR	N/A
2001	4 557	NR	NR	NR	NR	N/A
2000	3 780	NR	NR	NR	NR	N/A

Sources: SNL Metals & Mining, Impala Platinum Holdings (2000-2016), Northam Platinum (2000-2016), Lonmin Plc (2000-2016) Anglo American Platinum (2000-2016) and Sibanye (2013-2016).



Sources: SNL Metals & Mining, Impala Platinum Holdings (2000-2016), Northam Platinum (2000-2016), Lonmin Plc (2000-2016) Anglo American Platinum (2000-2016) and Sibanye (2013-2016).

Figure 4.3: Long-term platinum price assumptions relative to spot prices 2000-2016



Sources: SNL Metals & Mining, Impala Platinum Holdings (2000-2016), Northam Platinum (2000-2016), Lonmin Plc (2000-2016) Anglo American Platinum (2000-2016) and Sibanye (2013-2016).

Figure 4.4: Long-term PGM price assumptions relative to spot prices 2000-2016

4.4 The relationship between Mineral Reserves, long-term commodity prices and other modifying factors

Modifying factors, including long-term commodity prices, are used to convert Mineral Resources to Mineral Reserves. Therefore, it is to be expected that there would be a relationship between the change in modifying factors and changes in Mineral Reserve estimates. While Appleyard (2001) suggested that Mineral Reserves are most sensitive to commodity prices among the applied modifying factors, the other modifying factors are also important in the estimation process. This research study aimed to establish the relationship between the Mineral Reserve estimates of South African gold and platinum mining companies and their reported modifying factors. The coefficient of determination (R^2) was used to assess the relationship between Mineral Reserve estimates and their associated modifying factors. R^2 measures the correlation between two variables by determining how changes in the independent variable affect the dependent variable. R^2 uses regression to determine the fit between two sets of variables, and therefore measures the strength of the

relationship between them. R^2 values often range between 0 and 1, with values closer to 1 indicating stronger relationships. R^2 can be negative, but this is often an indication of an inappropriate model for the data being assessed or an undefined intercept (Statistics How To, (n.d.)). To assess the relationship between Mineral Reserve estimates and modifying factors, the Mineral Reserves were plotted on the y-axis as the dependent variable with the corresponding modifying factors plotted on the x-axis as the independent variables. This was done to determine the R^2 values based on linear relationships between the Mineral Reserves of South African gold and platinum companies between 2000 and 2016, and their respective modifying factors. A rating scale for the R^2 values was developed, as shown in Table 4.78, to rank the quality of the correlations between the Mineral Reserves and modifying factors. Table 4.79 shows the R^2 values for the linear relationships between the Mineral Reserves of South African gold mining companies and their associated modifying factors from 2000 to 2016.

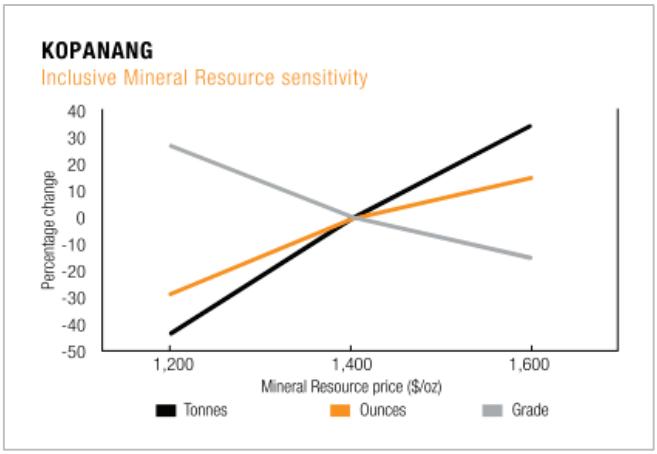
Table 4.78: Rating scale for R^2 values for the linear relationship between Mineral Reserves and modifying factors

Coefficient of determination (R^2)	**0 -0.4**	**0.4-0.6**	**0.6 - 1.0**
Correlation Rating	Poor	Moderate	Good
Colour	Red	Orange	Green

Table 4.79 shows that on average AGA's Mineral Reserves between 2000 and 2016 (for the South African operations) had the strongest linear relationship with gold price (ZAR-denominated), as gold price demonstrated the highest average R^2 value amongst the modifying factors of the Mineral Reserves for AGA's operations. The average R^2 values for MCF and stoping width demonstrated moderate relationships with the Mineral Reserves, while the other declared modifying factors appear to have had poor relationships with the Mineral Reserves.

Kopanang's Mineral Reserves demonstrated the highest R^2 values for gold price and stoping width, indicating that these are the modifying factors to which the Kopanang Mineral Reserves were most sensitive (Table 4.79). A moderate relationship was demonstrated between the Kopanang Mineral Reserves and metallurgical recovery, while weak relationships could be observed with the cut-off

grade, MCF and dilution modifying factors. In its sensitivity analysis of the Kopanang 2016 Mineral Resources (Figure 4.5), AGA stated that Kopanang is very sensitive to changes in gold price as it is a mature mine with a declining gold grade profile; the R^2 analysis supports this statement (Anglo Gold Ashanti, 2016).



Source: Anglo Gold Ashanti (2016)

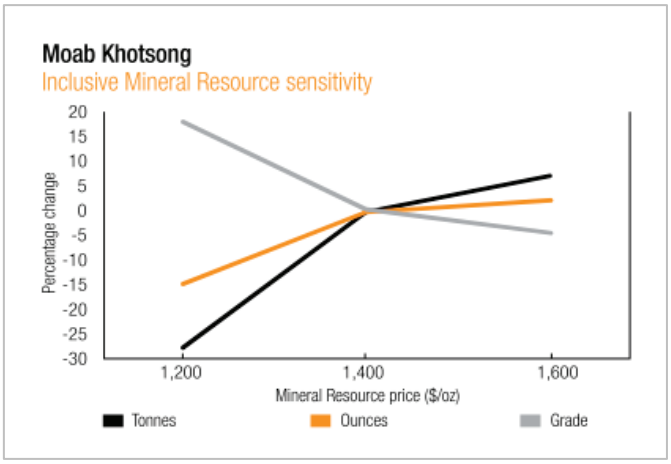
Figure 4.5: Kopanang 2016 Mineral Resource sensitivity analysis

The Moab Khotsong Mineral Reserves appear to have had a weak relationship with changes in long-term gold price assumptions, as shown by the low R^2 in Table 4.79. The 2016 Mineral Resource sensitivity analysis (Figure 4.6) conducted by AGA indicated that Moab Khotsong is not sensitive to price increases, due to its structural constraints, but is sensitive to price decreases (Anglo Gold Ashanti, 2016). The apparent lower correlation between Moab Khotsong's Mineral Reserves and gold price can also be explained by some of the major year-on-year changes in the Mineral Reserves, which were not related to gold price changes. In 2005, Moab Khostong's Mineral Reserves decreased by 60%, from 9Moz in 2004 to 3.6Moz, mainly due to the removal of 4.1Moz of the Phase 2 extension project from the mine plan; while the ZAR-denominated long-term gold price only decreased by 8% (Anglo Gold Ashanti, 2005). In 2007, the Moab Khotsong Mineral Reserves increased by 129% due to the addition of 3.8Moz associated with Project Zaaiplaats, which was a project to access deeper mining blocks, while the long-term gold price (ZAR/kg) only increased by 29% (Anglo Gold Ashanti, 2007). These non-gold price related adjustments to Moab Khotsong Mineral Reserves contributed to the low correlation between gold price and the Mineral Reserves observed in Table 4.79, if the effect

of the additions and removals of the project ounces was removed a higher R^2 would have been observed.

Table 4.79: R^2 values of the linear relationship between South African gold mining company Mineral Reserves and modifying factors

Mineral Reserves		Modifying Factor R^2 Values							
Company	**Operation**	**Gold Price**	**Cut-off grade**	**Mine Call Factor**	**Metallurgical Recovery**	**Stoping Width**	**Dilution**	**Cut-off Cost**	**Mining Loss**
Anglo Gold Ashanti	Kopanang	0.93	0.00	0.05	0.52	0.80	0.03	NR	NR
	Moab Khotsong	0.05	0.07	0.61	0.01	0.15	0.08	NR	NR
	Mponeng	0.56	0.04	0.57	0.07	0.51	0.01	NR	NR
	Tau Tona	0.86	0.16	0.57	0.59	0.61	0.23	NR	NR
	Great Noligwa	0.84	0.00	0.94	0.59	0.58	0.13	NR	NR
	Savuka	0.45	0.04	0.07	0.01	0.04	0.00	NR	NR
	Tau Lekoa	0.49	0.00	0.09	0.71	0.27	0.26	NR	NR
	Surface Operations	0.59	0.71	NR	0.58	N/A	N/A	NR	N/A
	Average	**0.60**	**0.13**	**0.41**	**0.39**	**0.42**	**0.11**	**NR**	**NR**
Harmony Gold	Dornkop	0.54	0.49	0.29	0.12	0.03	NR	0.19	NR
	Kusasalethu	0.59	0.90	0.53	0.65	0.07	NR	0.97	NR
	Target 1	0.85	0.32	0.14	0.33	N/A	0.06	0.63	NR
	Target 3	0.58	0.08	0.00	0.29	0.28	NR	0.17	NR
	Tshepong	0.72	0.00	0.37	0.79	0.88	NR	0.06	NR
	Phakisa	0.54	0.59	0.25	0.02	0.42	NR	0.75	NR
	Bambanani	0.88	0.01	0.37	0.25	0.00	NR	0.73	NR
	Unisel	0.82	0.23	0.69	0.48	0.44	NR	0.67	NR
	Masimong	0.61	0.06	0.81	0.00	0.61	NR	0.76	NR
	Joel	0.75	0.75	0.06	0.07	0.58	NR	0.25	NR
	Free State Surface Operations	0.51	0.35	0.00	0.03	N/A	NR	0.47	NR
	Kalgold	0.23	0.00	0.00	0.02	N/A	0.46	0.00	NR
	Evander	0.06	NR	0.47	0.31	0.17	NR	NR	NR
	Merriespruit	0.68	NR	0.22	0.98	0.56	NR	NR	NR
	Average	**0.60**	**0.32**	**0.30**	**0.31**	**0.37**	**0.26**	**0.47**	**NR**
Gold Fileds	South Deep	0.56	0.73	0.02	0.44	NR	0.22	NR	0.50
	Beatrix Gold Mine	0.60	0.35	0.83	0.01	NR	0.01	NR	0.83
	Kloof-Driefontein Complex	0.67	0.05	0.10	0.00	NR	0.84	NR	0.10
	Average	**0.61**	**0.38**	**0.32**	**0.15**	**NR**	**0.36**	NR	**0.48**
Sibanye Gold	Beatrix	0.18	0.13	0.55	0.00	0.12	NR	NR	NR
	Driefontein	0.33	0.54	0.68	0.00	0.10	NR	NR	NR
	Kloof	0.41	0.03	0.00	0.51	0.67	NR	NR	NR
	Cooke Operations	0.95	0.29	0.82	0.17	0.03	NR	NR	NR
	Average	**0.47**	**0.25**	**0.51**	**0.17**	**0.23**	**NR**	**NR**	**NR**
OVERALL AVERAGE		**0.57**	**0.27**	**0.39**	**0.25**	**0.34**	**0.24**	**0.47**	**0.48**

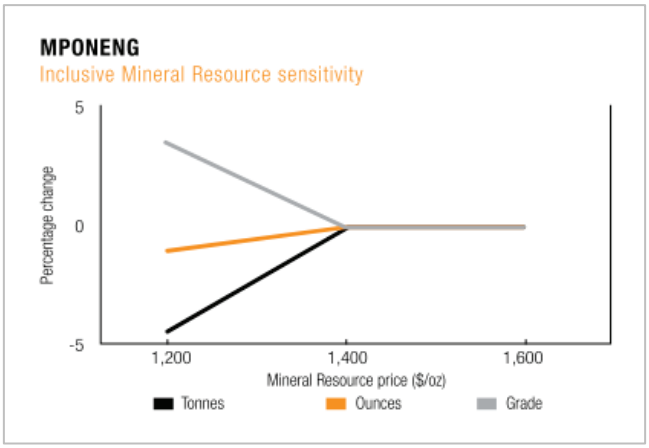


Source: Anglo Gold Ashanti (2016)

Figure 4.6: Moab Khotsoong 2016 Mineral Resource sensitivity analysis

The relationships between the Moab Khotsong Mineral Reserves and the technical modifying factors also appeared to have been weak, with only the MCF showing a good correlation due to its relatively high R^2 value (Table 4.79). The apparently significant relationship between MCF and Moab Khotsong's Mineral Reserves was demonstrated by a reduction of 1.3Moz in the Mineral Reserves in 2005, which amounted to 14% of the 9Moz reported in 2004, due to changes in the MCF (Anglo Gold Ashanti, 2005).

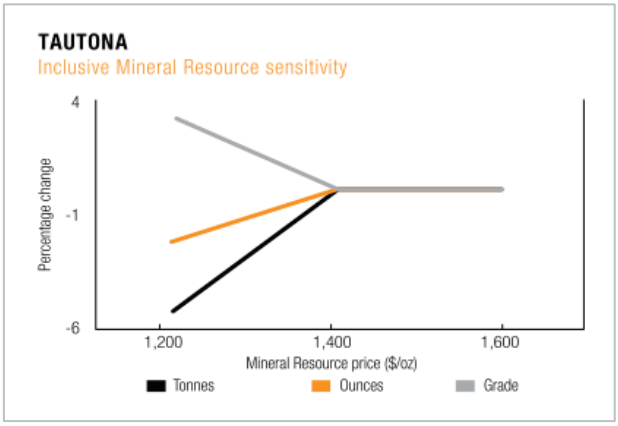
Based on the 2000 to 2016 declaration, Mponeng's Mineral Reserves appear to have had moderate relationships with long-term gold price, MCF and stoping width, as shown in Table 4.79. However, AGA's 2016 Mineral Resource sensitivity analysis for Mponeng indicated that the Mineral Resources, as shown in Figure 4.7, were not sensitive to changes in gold price (Anglo Gold Ashanti, 2016). The Mponeng Mineral Reserves appear have had poor relationships with the other modifying factors.



Source: Anglo Gold Ashanti (2016)

Figure 4.7: Mponeng 2016 Mineral Resource sensitivity analysis

The Tau Tona Mineral Reserves have shown a good relationship with long-term gold price between 2000 and 2016, due to the high R^2 value shown in Table 4.79. However, in 2016 AGA stated that the Tau Tona Mineral Resources were not sensitive to gold price (Figure 4.8) as it is a mature operation with limited operating flexibility (Anglo Gold Ashanti, 2016). Musingwini et al. (2007) stated that mine layouts and schedules without operating flexibility are unable to adapt to changes in economic and technical conditions and can therefore not take advantage of improvements in commodity prices. A good relationship was also observed with stoping width, while moderate relationships were observed for MCF and metallurgical recovery. As with the other AGA underground operations, the Tau Tona Mineral Reserves did not indicate a strong direct relationship with cut-off grade.



Source: Anglo Gold Ashanti (2016)

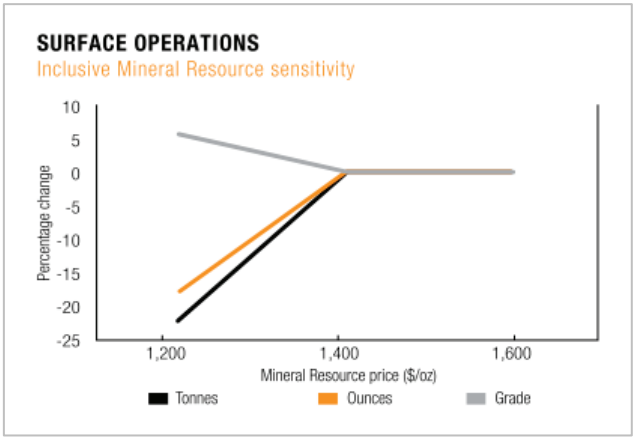
Figure 4.8: Tau Tona 2016 Mineral Resource sensitivity analysis

Great Noligwa's Mineral Reserves indicated the strongest relationship with MCF, relative to the other modifying factors, as shown by the high R^2 in Table 4.79. Long-term gold price follows MCF closely in terms of its relationship with the Great Noligwa Mineral Reserves. Moderate relationships were observed between the Great Noligwa Mineral Reserves and metallurgical recovery and stoping width. Cut-off grade and dilution demonstrated poor relationships.

The Savuka Mineral Reserve declarations between 2000 and 2012 demonstrated a moderate relationship to changes in long-term gold prices, as shown by the R^2 value in Table 4.79. The relatively weaker relationship between the Savuka Mineral Reserve and long-term gold prices is probably due to the fact that Savuka was a mature operation with limited operating flexibility, which was closed in 2012, thus its gold price upside was limited (Anglo Gold Ashanti, 2012). The historical Savuka Mineral Reserves indicated weak relationships with all the other reported modifying factors.

The Tau Lekoa Mineral Reserves between 2000 and 2009, indicated that metallurgical recovery was the modifying factor to which the Mineral Reserves appeared most sensitive (Table 4.79). The Tau Lekoa Mineral Reserves demonstrated a modest relationship with long-term gold price and poor relationships with the other reported modifying factors.

The AGA Surface Operations' Mineral Reserves between 2000 and 2016 demonstrated a goog relationship to changes in cut-off grade, as shown by the R^2 value in Table 4.79. Moderate relationships were observed for gold price and metallurgical recovery. In its 2016 sensitivity analysis of the Surface Operations Mineral Resources (Figure 4.9), AGA stated that the Surface Operations were sensitive to gold price reductions due to the marginal nature of the operations (Anglo Gold Ashanti, 2016).



Source: Anglo Gold Ashanti (2016)

Figure 4.9: Surface Operations 2016 Mineral Resources sensitivity analysis

The Mineral Reserves for Harmony's South African operations between 2000 and 2016, on average, demonstrated the strongest relationship with long-term gold price (Table 4.79). A moderate relationship was also observed for cut-off cost, while the relationships with the other modifying factors demonstrated poor relationships. Harmony's Doornkop Mineral Reserves from 2000 to 2016 have shown the strongest relationship to changes in cut-off cost, while long-term gold price and cut-off grade demonstrated moderate relationships, as shown by the R^2 values in Table 4.79. The other modifying factors indicated poor relationships. The Kusasalethu Mineral Reserves between 2000 and 2016 appear to have been mostly been sensitive to changes in cut-off cost and cut-off grade and metallurgical recovery, as shown by the R^2 values in Table 4.79. Moderate relationships were observed for the gold price and MCF, while the other modifying factors demonstrated poor relationships with the Kusasalethu Mineral Reserves.

The Target 1 Mineral Reserves between 2004 and 2016 demonstrated good relationships with long-term gold price and cut-off cost, while poor relationships were observed for the other modifying factors, as shown by the R^2 values in Table 4.79.The Target 3 Mineral Reserves from 2010 to 2014 appear to have had a moderate relationship with long-term gold price and poor relationships with all the other modifying factors. The Tshepong Mineral Reserves from 2005 to 2016 demonstrated good relationships with long-term gold prices, metallurgical recovery and stoping width; but weak relationships with the other modifying factors, as shown by the R^2 values in Table 4.79. The poor relationship between the Tshepong Mineral

Reserves and cut-off grade is demonstrated by the fact that cut-off grade remained unchanged from 2011 to 2016, even though there had been changes in the Mineral Reserves in that period.

The Phakisa Mineral Reserves between 2005 and 2016 appear to have been most sensitive to changes in cut-off cost, while long-term gold price, cut-off grade and stoping width demonstrated moderate relationships, as shown by the R^2 values in Table 4.79. The Bambanani Mineral Reserves between 2005 and 2016 demonstrated the strongest relationships to changes in long-term gold prices and cut-off, while showing poor relationships with the other modifying factors, as shown by the R^2 values in Table 4.79. The Unisel Mineral Reserves between 2005 and 2016 appear to have been most sensitive to changes in long-term gold price, followed by MCF and cut-off grade. Moderate relationship were observed with metallurgical recovery and stoping, while only the relationship with cut-off grade was poor.

The MCF modifying factor appears to have had the strongest influence on the Masimong Mineral Reserves between 2005 and 2016, followed by cut-off cost and long-term gold prices, as shown by the R^2 values in Table 4.79. The plant recovery factors had almost no influence on the Masimong Mineral Reserves as it remained fairly unchanged between 2007 and 2016, even as there were changes in the Mineral Reserves. The Joel Mineral Reserves between 2005 and 2016 appear to have had good relationships with long-term gold price and cut-off grade, while the relationship with stoping width was moderate and poor relationships were observed for the other modifying factors. The Kalgold Mineral Reserves between 2000 and 2016 demonstrated only a moderate relationship with dilution and poor relationships with all the other modifying factors.

The Mineral Reserves of the Free State Surface Operations from 2000 to 2016 demonstrated moderate relationships to changes in long-term gold price and cut-off cost, while the relationships with the other modifying factors were weak, as shown by the R^2 values in Table 4.79. The Mineral Reserves of the Free State Surface Operations have had no relationship with MCF, as the MCF assumption had remained unchanged at 100%, even as the Mineral Reserves changed on an annual

basis. The Evander Mineral Reserves from 2000 to 2011 appear to have had a moderate relationship to changes in MCF, while demonstrating poor relationships with the other modifying factors. The Merriespruit Mineral Reserves from 2005 to 2016 appear to have been most sensitive to changes in the plant recovery modifying factors, followed by long-term gold prices. A moderate relationship was observed for stoping width and a poor relationship was identified with MCF.

On average, the Mineral Reserves for Gold Fields' South African operations between 2000 and 2016 appear to have had good relationships with changes in long-term gold price and moderate relationships with mining losses (Table 4.79). On average the relationships with the other modifying factors were poor. The South Deep Mineral Reserves from 2007 and 2016 appear to have had a good relationship with cut-off grade and moderate relationships with long-term gold price, metallurgical recovery and mining losses. The Beatrix Mineral Reserves from 2000 to 2011 appear to have had good relationships to changes in MCF, mining losses and long-term gold price. The KDC Mineral Reserves from 2000 to 2011 appear to have had good relationships with only long-term gold price and dilution, while the relationships with the other modifying factors were poor.

In the period between 2012 and 2016, Sibanye Gold's Mineral Reserves appear to have had (on average) moderate relationships with long-term gold prices and MCF, as shown by the R^2 values in Table 4.79; while having poor relationships with the other modifying factors. The Beatrix and Driefontien Mineral Reserves from 2012 to 2016 both appear to have been most sensitive to changes in MCF. While the Kloof Mineral Reserves demonstrated a strong relationship with stoping width and moderate relationships with metallurgical recovery and long-term gold price. The Mineral Reserves of the Cooke Operations between 2013 and 2016 appear to have been most sensitive to changes in the long-term gold price, followed by MCF.

Based on the overall averages of the R^2 values (Table 4.79) for the linear relationships between the Mineral Reserves and modifying factors of South African gold mining companies between 2000 and 2016, it appears that these Mineral Reserves were most sensitive to the long-term gold price modifying factor. The cut-off cost and mining loss modifying factors appear to have also had moderate

relationships with these Mineral Reserve estimates. Poor relationships were observed (on overall average R^2 basis) between these gold Mineral Reserve estimates and the cut-off grade, MCF, metallurgical recovery, stoping width and dilution modifying factors. This suggests that the Mineral Reserves of South African gold mining companies were not particularly sensitive to these modifying factors in the period between 2000 and 2016.

Due to the less detailed nature of Mineral Reserve reporting by the major South African platinum mining companies, only a limited assessment of the relationships between their Mineral Reserves and modifying factors could be conducted. For the Northam operations only an assessment of the relationship between the Mineral Reserves and platinum price could be conducted, as only the long-term platinum price modifying factor is reported consistently from 2003. For the Lonmin Mineral Reserves the relationship with the 6E PGM long-term prices and the dilution and mining loss modifying factors was assessed. For the Implats Mineral Reserves the relationship with the long-term platinum, palladium and rhodium prices was assessed. And for the Amplats Mineral Reserves only the relationship with the paylimit was assessed. The R^2 values for the linear relationships between the Mineral Reserves of South African platinum mining companies and their associated modifying factors from 2000 to 2016 are shown in Table 4.80.

Table 4.80 shows that on average the Northam Mineral Reserves between 2003 and 2016 demonstrated a poor relationship with the long-term platinum price, while the other modifying factors were not reported. The Booysendal Mineral Reserves demonstrated a good relationship to changes in the long-term platinum price, while the Pandora Mineral Reserves appear to have had a moderate relationship with the long-term platinum price. The Zondereinde Mineral Reserves demonstrated a poor relationship with the long-term price. The Dwaalkop Mineral Reserves appear to have had no relationship platinum price as the Mineral Reserves remained unchanged between 2010 and 2015, even as Northam’s long-term platinum price changed.

Table 4.80: R^2 values of the linear relationship between South African platinum mining company Mineral Reserves and modifying factors

Mineral Reserves		Modifying Factor R^2 Values								
Company	**Operation/Reef**	**Platinum Price**	**Palladium Price**	**Rhodium Price**	**Gold Price**	**Ruthenium Price**	**Iridium Price**	**Dilution**	**Mining Loss**	**Paylimit**
Northam	Zondereinde mine	0.09	NR	NR	NR	NR	NR	NR	NR	NR
	Dwaalkop	0.00	NR	NR	NR	NR	NR	NR	NR	NR
	Booysendal North mine	0.72	NR	NR	NR	NR	NR	NR	NR	NR
	Pandora	0.46	NR	NR	NR	NR	NR	NR	NR	NR
	Average	**0.32**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**
Lonmin	Marikana	0.93	0.79	0.03	0.78	0.00	0.96	0.07	0.49	NR
	Pandora	0.74	0.66	0.17	0.79	0.84	0.76	0.22	0.56	NR
	Limpopo	0.20	0.13	0.04	0.11	0.45	0.34	0.97	0.97	NR
	Average	**0.62**	**0.53**	**0.08**	**0.56**	**0.43**	**0.69**	**0.42**	**0.67**	**NR**
Implats	Impala	0.04	0.01	0.03	NR	NR	NR	NR	NR	NR
	Marula	0.32	0.06	0.05	NR	NR	NR	NR	NR	NR
	Two Rivers	0.25	0.02	0.01	NR	NR	NR	NR	NR	NR
	Zimplats	0.37	0.33	0.17	NR	NR	NR	NR	NR	NR
	Mimosa	0.02	0.23	0.34	NR	NR	NR	NR	NR	NR
	Average	**0.20**	**0.13**	**0.12**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**
Amplats	Merensky	NR	NR	NR	NR	NR	NR	NR	NR	0.19
	UG2	NR	NR	NR	NR	NR	NR	NR	NR	0.48
	Platreef	NR	NR	NR	NR	NR	NR	NR	NR	0.55
	Main Sulphide Zone	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Average	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**	**0.41**
OVERALL AVERAGE		**0.38**	**0.33**	**0.10**	**0.56**	**0.43**	**0.69**	**0.42**	**0.67**	**0.41**
		0.41								

The Lonmin Mineral Reserves from 2005 to 2016 appear to have had good relationships (on average) with the long-term platinum and iridium prices, as well as the mining loss factor, as shown in Table 4.80. The Marikana Mineral Reserves appear to have had good relationships with the long-term platinum, palladium, gold and iridium prices; while the relationship with the mining loss factor was moderate. The Pandora Mineral Reserves appear to have had good relationships with five of the 6E PGMs except, except for Rhodium, while also demonstrating a moderate relationship with the mining loss factor. The Limpopo Mineral Reserves appear to have had poor relationships with the long-term prices five of the 6E PGMs, except ruthenium which demonstrated a moderate relationship. Good relationships appear to have existed with dilution and the mining loss factor.

The Mineral Reserves for all on the Implats operations from 2003 to 2016 appear had poor relationships with reported long-term platinum, palladium and rhodium prices. On average the Mineral Reserves for the Mineral Reserves of the different Amplats reef horizons demonstrated a moderate relationship with paylimits, as shown in Table 4.80. However, the Merensky Reef Mineral Reserves demonstrated a poor relationship with paylimit.

Based on the overall R^2 averages shown in Table 4.80, the Mineral Reserves of South African platinum mining companies between 2000 and 2016 demonstrated moderate relationships with long-term PGM prices, dilution and paylimit. A good relationship appears to have existed with the mining loss factor. However due to the limited reporting of modifying factors by the South African platinum mining companies between 2000 and 2016, there were limited data points for most of the modifying factors for which the linear relationship assessments were performed, therefore the overall R^2 values may not be representative of actual relationships.

4.5 The ideal commodity price range for the Mineral Reserve estimates of South African gold and platinum mining companies

The process of determining long-term commodity prices for Mineral Reserve estimation is complicated by the fact that commodity price forecasting is a complex process in which supply and demand dynamics, which are not always simple to quantify, have to be assessed and translated into reasonable forecasts. Although there are a number theories that relate to commodity price forecasting, including the Prebisch-Singer hypothesis and the mean-reversion theory, commodity price cycles are often subject to shocks which the existing theories are not able to predict; this makes commodity price forecasting challenging. When making their long-term commodity price assumptions, mining companies can at best hope to be within a reasonable range of future prices, as precise forecasts of commodity prices are unattainable. This research study therefore aimed to determine the reasonable range for the Rand-denominated commodity prices of South African platinum and gold Mineral Reserve estimates.

The financial statements of companies capture the value created and contained within companies at any point in time. Financial statements help to inform the shareholders of a company or any other interested party about the performance of the company. As a result of their incorporation in different countries and their listing on various stock exchanges, mining companies also have to report the value of their businesses through their financial statements. Commodity prices are key value drivers for mining companies, therefore variations in commodity prices, both forecast and actual, will affect the quantum of value reported by mining companies in their financial statements. Mineral Reserves, while being the single most important asset for mining companies, are not reported on the balance sheets of mining companies, except when mineral assets are acquired from a third party and value is ascribed to the mining rights as part of the purchase price allocation (PPA). For assets that are developed by mining companies, the capital expenditure for constructing and developing the mine would be recorded on the balance sheet (Njowa, 2017). The assets of mining companies are often captured in financial statements as either tangible assets such as property plant and equipment or intangible assets associated with mining rights. The value of these assets is often affected by the long-term commodity prices assumed by mining companies.

A key accounting standard which relates to the variation in the value of assets reported by mining companies (and companies in general) is the International Accounting Standard (IAS) 36, which relates to the impairment of assets. IAS 36 states that the value of the assets of a company should not be carried (or recorded) on financial statements at a value greater than the value in use or fair value less cost of disposal (net selling price). If the carrying value exceeds the recoverable value, then a company should recognise an impairment. IAS 36 does not cover financial assets, inventories, deferred tax, agricultural assets, insurance contract assets, investment property and other assets which are covered in other accounting standards (IFRS Foundation, (n.d.)). Investopedia (n.d.) defines a financial asset as "*a tangible liquid asset that gets its value from a contractual claim. Cash, stocks, bonds, bank deposits and the like are examples of financial assets. Unlike land, property, commodities or other tangible physical assets, financial assets do not necessarily have inherent physical worth*". A non-financial assets is defined as "*an*

asset with a physical value. Examples include real estate, equipment, machinery or a vehicle" (Investopedia, n.d.).

The impairments recorded by mining companies for their non-financial assets can be considered to be an indicator of the effects of their long-term commodity price assumptions. When mining companies record the value of their property, plant and equipment or the value of their mining rights on their financial statements using a commodity price that is considerably higher than prevailing commodity price, these companies may be required to record an impairment as the recoverable value of these assets may exceed the carrying value, in line with the provisions of IAS 36. An assessment of the non-financial asset impairments of South African gold and platinum mining from 2000 to 2016, gives an indication of the relationship between asset carrying values as represented by long-term commodity prices and recoverable values as represented by prevailing spot prices. It should be noted that long-term commodity prices used by a mining company for Mineral Reserve estimation may differ from the long-term prices used to test the assets of a mining company for impairment. However, it is the author's view that the same long-term commodity prices should be used for Mineral Reserve estimation and impairment testing, as both of these exercises serve the purpose (amongst others) of establishing the economic viability of a mining company's mineral assets. A misalignment in the long-term commodity prices used for both of these exercises represents a misaligned view on the value of a mining company's principal asset; the Mineral Reserves.

Mining companies can record impairments due to their previously assumed long-term prices being greater than prevailing and forecast commodity prices, and therefore their carrying values being lower than the recoverable amount. Impairments can also be recorded when long-term commodity prices are lower than prevailing prices, as the perceived recoverable value may be lower than current carrying values. Therefore impairments can occur as a result of either excessive optimism or conservatism when mining companies determine their long-term commodity price assumptions. Although mining asset impairments can be affected by operational issues which affect the recoverability of asset values, commodity prices movements are a common feature in the reasons for impairments.

The major South African gold mining companies have mostly assumed Rand-denominated long-term gold prices lower than spot prices between 2000 and 2016. However, these companies have recorded significant impairments in this period, as shown in Table 4.81. This shows that having a conservative view on long-term prices does not prevent the incurring of impairments. However, Figure 4.10 shows that when the long-term gold price assumptions of the South African gold mining companies were within 5% (both above and below) of spot prices, minimal impairments were recorded. The majority of impairments were recorded outside the +/-5% long-term gold price to spot price range, which suggests that this could be an ideal gold price range for South African gold mining companies to maintain.

Table 4.81: Long-term gold prices and gold mining company impairments

Year	Spot Gold Price (ZAR/kg)	Anglo Gold Ashanti			Harmony Gold			Gold Fields			Sibanye Gold		
		Long-Term Gold Price (ZAR/kg)	Long-Term Gold Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Gold Price (ZAR/kg)	Long-Term Gold Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Gold Price (ZAR/kg)	Long-Term Gold Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Gold Price (ZAR/kg)	Long-Term Gold Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)
2016	590 506	530 000	(10)%	42	475 107	(20)%	(43)	550 000	(7)%	1 080	490 000	(17)%	1 172
2015	475 767	431 000	(9)%	65	450 026	(5)%	3 471	500 000	5%	861	430 000	(10)%	0
2014	441 465	398 452	(10)%	6	425 064	(4)%	1 439	400 000	(9)%	141	420 000	(5)%	(319)
2013	437 828	360 252	(18)%	3 109	400 148	(9)%	2 735	400 000	(9)%	6 778	410 000	(6)%	821
2012	440 417	290 064	(34)%	392	339 833	(23)%	(60)	380 000	(14)%	718	380 000	(14)%	0
2011	367 051	269 841	(26)%	88	279 888	(24)%	264	310 000	(16)%	68	N/A	N/A	N/A
2010	288 628	238 028	(18)%	634	250 149	(13)%	331	265 000	(8)%	258	N/A	N/A	N/A
2009	265 204	227 627	(14)%	(5 113)	224 975	(15)%	546	230 000	(13)%	1 210	N/A	N/A	N/A
2008	231 573	200 698	(13)%	14 793	179 883	(22)%	316	150 000	(35)%	51	N/A	N/A	N/A
2007	157 820	148 536	(6)%	6	115 022	(27)%	(134)	100 000	(37)%	3	N/A	N/A	N/A
2006	131 587	114 939	(13)%	44	104 972	(20)%	(216)	92 000	(30)%	0	N/A	N/A	N/A
2005	91 065	86 807	(5)%	300	91 996	1%	1 513	92 000	1%	261	N/A	N/A	N/A
2004	85 121	94 764	11%	8	91 996	8%	19	90 000	6%	426	N/A	N/A	N/A
2003	88 522	78 769	(11)%	327	92 948	5%	886	95 000	7%	0	N/A	N/A	N/A
2002	105 194	94 041	(11)%	0	94 845	(10)%	457	95 111	(10)%	0	N/A	N/A	N/A
2001	75 056	71 262	(5)%	1 394	67 388	(10)%	225	69 992	(7)%	2 121	N/A	N/A	N/A
2000	62 279	NR	NR	2 632	60 033	(4)%	0	NR	NR	100	N/A	N/A	N/A
TOTAL/AVERAGE			**(12)%**	**18 727**		**(11)%**	**11 749**		**(11)%**	**14 076**		**(10)%**	**1 674**

Sources: SNL Metals & Mining, Anglo Gold Ashanti (2000-2016), Harmony Gold (2000-2016), Gold Fields (2000-2016) and Sibanye Gold (2013-2016).

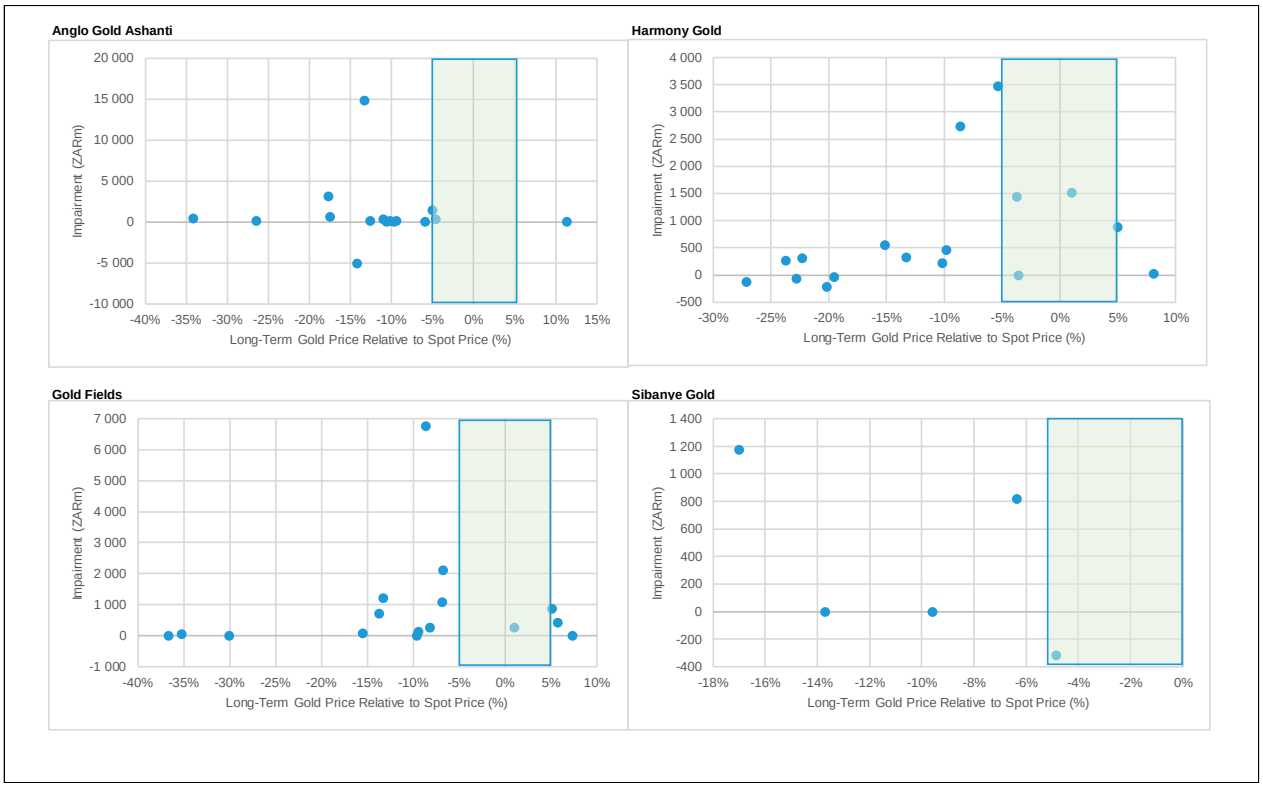


Figure 4.10: Long-term gold prices and gold mining company impairments

Among South Africa's major platinum mining companies, Implats and Lonmin have on average assumed long-term platinum prices that were higher than spot prices between 2003 and 2016, as shown in Table 4.82. Northam assumed conservative platinum prices in the earlier part of the period and higher prices in the latter part, resulting on an average 0% variance over the period. As Amplats has historically not reported its assumed long-term platinum price, therefore a comparison with spot could not be conducted. The major South African platinum mining have also recorded significant impairments in the 2000 to 2016 period, with Northam recording the least impairments (Table 4.82). Figure 4.11 shows that of the several impairments recorded by the major South African platinum mining companies from 2000 to 2016, very few impairments occurred in the +/-5% long-term platinum price to spot platinum price ratio range. This suggests that if this range is maintained for long-term platinum prices, impairments could be minimised.

Table 4.82: Long-term platinum prices and platinum mining company impairments

Year	Spot Platinum Price (ZAR/oz)	Impala Platinum			Northam Platinum			Lonmin Plc			Anglo American Platinum		
		Long-Term Platinum Price (ZAR/oz)	Long-Term Platinum Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Platinum Price (ZAR/oz)	Long-Term Platinum Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Platinum Price (ZAR/oz)	Long-Term Platinum Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)	Long-Term Platinum Price (ZAR/oz)	Long-Term Platinum Price Relative to Spot Price (%)	Non-Financial Asset Impairment (ZARm)
2016	14 525	18 648	28%	257	20 291	40%	(14)	20 729	43%	4 593	NR	NR	22
2015	13 421	17 718	32%	5 847	19 357	44%	264	18 632	39%	24 493	NR	NR	10 242
2014	15 009	26 760	78%	1 000	13 455	(10)%	0	16 785	12%	0	NR	NR	480
2013	14 339	18 778	31%	0	15 925	11%	0	16 785	17%	0	NR	NR	833
2012	12 720	16 080	26%	0	11 963	(6)%	32	14 875	17%	4 258	NR	NR	0
2011	12 488	22 560	81%	0	12 866	3%	0	15 200	22%	14	NR	NR	0
2010	11 792	27 716	135%	0	12 360	5%	0	14 904	26%	89	NR	NR	0
2009	10 211	20 879	104%	0	9 450	(7)%	17	14 400	41%	0	NR	NR	0
2008	12 980	24 083	86%	108	14 391	11%	0	12 000	(8)%	715	NR	NR	209
2007	9 192	11 085	21%	0	6 670	(27)%	0	9 208	0%	0	NR	NR	0
2006	7 733	7 850	2%	-583	5 850	(24)%	0	7 700	(0)%	0	NR	NR	0
2005	5 705	6 700	17%	1 034	4 950	(13)%	0	4 940	(13)%	0	NR	NR	0
2004	5 464	6 100	12%	0	4 347	(20)%	0	NR	N/A	0	NR	NR	0
2003	5 233	6 100	17%	0	5 004	(4)%	0	NR	NR	0	NR	NR	0
2002	5 688	NR	NR	0	NR	NR	11	NR	NR		NR	NR	0
2001	4 557	NR	NR	0	NR	NR	11	NR	NR	105	NR	NR	0
2000	3 780	NR	NR	0	NR	NR	0	NR	NR	0	NR	NR	
TOTAL/AVERAGE			**48%**	**7 663**		**0%**	**321**		**16%**	**34 267**			**11 786**

Sources: SNL Metals & Mining, Impala Platinum Holdings (2000-2016), Northam Platinum (2000-2016), Lonmin Plc (2000-2016) Anglo American Platinum (2000-2016).

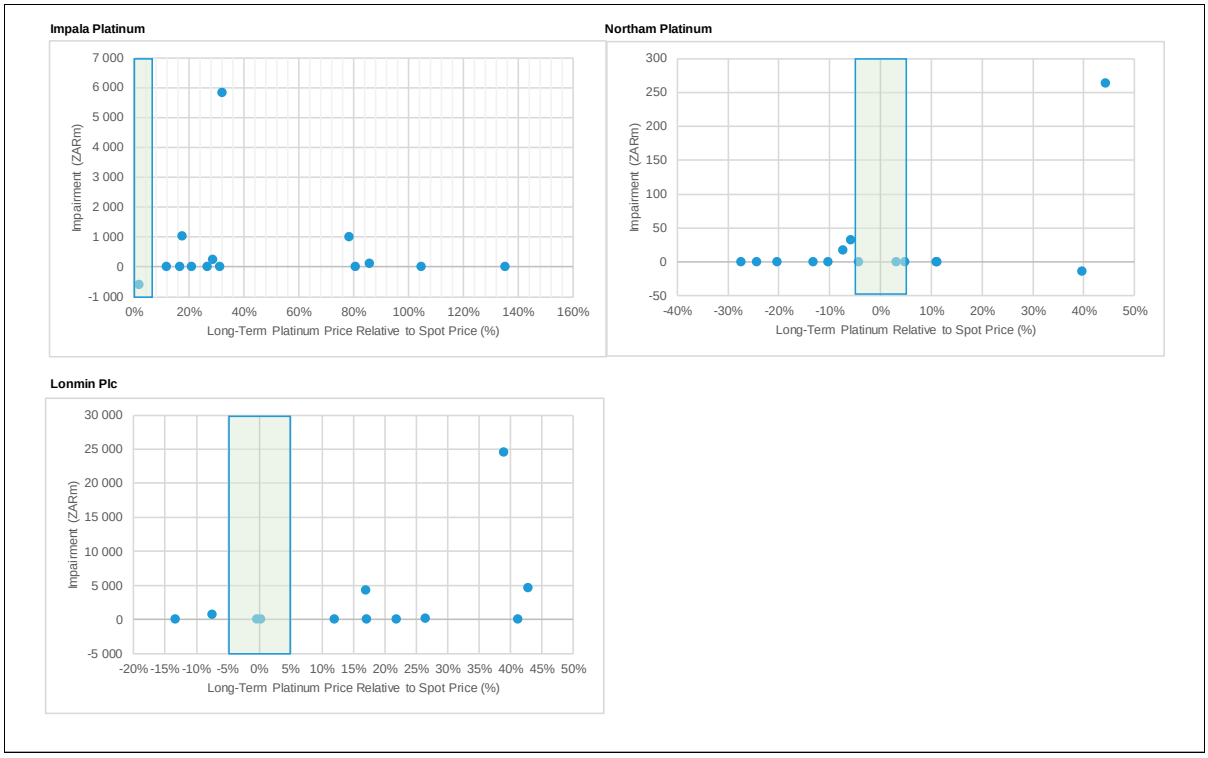


Figure 4.11: Long-term platinum prices and platinum mining company impairments

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research study evaluated the Mineral Reserve reporting of major South African gold and platinum mining companies from 2000 to 2016 to determine the extent to which the long-term commodity prices and other modifying factors used in Mineral Reserve estimation have been disclosed. The long-term commodity prices were also compared relative to historical spot prices to assess the quality of forecasting undertaken by South African gold and platinum mining companies. The relationships between the quantum of Mineral Reserves and long-term commodity price assumptions and the other modifying factors was also assessed to determine the extent to which changes in these assumptions affected Mineral Reserve estimates. An assessment of a potential range for the determination of long-term commodity prices was also conducted.

South Africa's major gold mining companies were found to have consistently reported the long-term gold prices used in their Mineral Reserves from 2001, a year after the introduction of the SAMREC Code. The detailed reporting of the other Mineral Reserve modifying factors was undertaken by AGA from 2002, followed by Harmony in 2005; Gold Fields' reporting of the other modifying factors has been less consistent and detailed over the period. Mineral Reserve reporting by South Africa's major platinum mining companies has been less detailed, as these companies only started reporting the long-term platinum prices used in Mineral Reserve estimation between 2003 and 2005. Amplats did not report its long-term platinum prices over the entire period between 2000 and 2016. The reporting of the other modifying factors by the platinum mining companies has also been limited. Amplats has mostly only reported paylimit ranges and Implats only began reporting technical modifying factors in 2016. The South African gold mining companies have reported long-term Rand-denominated gold prices that were lower than prevailing spot prices. The platinum mining companies have however been more optimistic in their long-term platinum price assumptions, by assuming prices that were commonly higher than prevailing spot prices. This suggests that in the period under review, South Africa's platinum mining companies were most likely to have reported ounces that were uneconomic as part of their Mineral Reserves.

Amongst the modifying factors used in Mineral Reserve estimation, the Mineral Reserves of South African gold and platinum mining companies appeared to have been most sensitive to changes in long-term gold and platinum prices between 2000 and 2016. Although the Mineral Reserves of some operations indicated greater sensitivity to changes in the other modifying factors, on an overall basis, changes in long-term gold and platinum prices appeared to have the greatest impact on Mineral Reserve estimates. An assessment of long-term gold and platinum prices relative to historical spot prices and their impact on the number of non-financial impairments recorded by South Africa's gold and platinum mining companies revealed that minimal impairments were recorded when long-term commodity prices were within 5% of prevailing spot prices. This suggests that if South Africa's gold and platinum mining companies keep their long-term commodity prices within 5% of spot prices, for Mineral Reserve estimation and the value in use assessment, they could potentially limit the number of impairments they incur.

5.2 Recommendations for future research work

This research study focused on the Mineral Reserve reporting and long-term commodity prices of South African gold and platinum mining companies, and how this has evolved since the introduction of the SAMREC Code in 2000. Future research work could focus on other commodities and mining jurisdictions to determine how effective the other international mineral reporting codes have been in improving the quality of Mineral Reserve reporting.

This research study has not developed a framework that could be used by mining companies when determining their long-term commodity price assumptions. The uncertainty associated with commodity price forecasting was discussed in this study, however no detailed solution is offered herein, except that of making long-term commodity price assumptions within 5% of spot prices to limit future impairments. There is scope for future research work to investigate frameworks for making reasonable long-term commodity price assumptions. As most commodities are subject to unique supply and demand dynamics, associated with their investment or industrial uses, the frameworks to be developed would have to focus on specific commodities or commodity groups. The frameworks would most likely

need to make use of stochastic mechanisms to account for the shocks to which commodity price cycles are routinely subjected. These commodity forecasting frameworks would also have to take account of regional dynamics, in terms of focusing on commodity prices denominated in local currencies as Rand-denominated prices displayed trends which differed to US Dollar prices.

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