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The Judicious Use of Environmental Sustainability Indicators in Support of Mine Closure in South Africa

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A full dissertation submitted in fulfilment of the requirements for the degree of Master of Science in Geography in the Faculty of Science at the University of Johannesburg

October 2014
PLAGIARISM DECLARATION

I declare that the work contained in this dissertation is my own original writing. Sources referred to in the creation of this dissertation have been appropriately acknowledged by explicit references. Other assistance received has been acknowledged. I have not knowingly copied or used the words or ideas of others without such acknowledgement. This work has not previously been submitted to any other university or institution for examination.


Mr. M. Milaras

Signed ___________________  Date ___________________
ACKNOWLEDGEMENTS

I would particularly like to thank my supervisor Dr. Fethi Ahmed for his guidance and trust in my capacity; as well as Ms. Tracey McKay and Dr. Phillipus Crouse for being models of an exacting academic ethic. To my anonymous examiners: my gratitude for your time and effort; I trust you shall at the very least enjoy the read.

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There are many I have not mentioned by name, but you know who you are, and what you have kindly offered me in my knowing you.

And in conclusion I would like to acknowledge my own efforts in completing this dissertation. It has been a remarkable honour and a fascinating journey.

600 years ago, Leonardo da Vinci had the following to say about mining: “That shall be brought forth from the dark and obscure caves, which will put the whole human race in great anxiety, peril and death. Too many that seek them, after many sorrows they will give delight, and to those who are not in their company, death with want and misfortune. This will lead to the commission of endless crimes; this will persuade bad men to assassinations, robberies and enslavement, and by reason of it each will be suspicious of his partner. This will deprive cities of their happy condition; this will take away the lives of many; this will make men torment one another... For this the vast forests will be devastated of their trees; for this, endless animals will lose their lives.” (Da Vinci, 1992: xi).

This dissertation is thus dedicated to this Earth our home, which we so mine; in the hope that it may lend us some wisdom and Her some succour.
ABSTRACT

South Africa is a mineral rich country with a long established mining sector. With the worldwide advent of the discourse around and conscious need to practice sustainable development, mining has needed to be framed and tackled from a sustainable development perspective. By its very nature mining of a finite ore body is a temporary land use. Upon reaching the end of viable economic production, a mine will need to be ‘closed’. Historically, closure has been environmentally inept leaving lasting negative consequences. With modern sustainable development principles driving mining practice and integrated into South African legislation, these negative impacts should be ameliorated upon closure; whereby mine closure should contribute positively, leaving an environmentally sustainable land use legacy for future development. Nevertheless in practice, closure is still often poorly planned for and executed; with near on unmitigateable environmental impacts remaining. Thus the research problem stemmed from an interest in seeking to determine if progress toward or away from this ideal of sustainable mine closure could be measured. To tackle this question it was deemed pertinent to interrogate the underlying sustainability principles in international and South African mining and closure policy. With these principles established, South African mine closure legislation was reviewed and found to be reasonably robust in terms of the inclusion of sustainability principles. The following step of the research was to survey a quorum of experts as to environmental sustainability indicators, and current and best mine closure practices in South Africa. Participants were gathered utilising the ‘snowball’ method of referral. A predominantly open-ended questionnaire was designed, and administered using the online platform Google Forms. Responses were collated and interpreted by means of a qualitative narrative, with quantitative analysis where possible. Findings include that: South African closure professionals tend to be employed in the private sector; South Africa’s top five economic minerals dominated 80% of closure experts’ experience; and practitioners address a comprehensive range of mine closure aspects throughout the mine-life cycle. In particular numerous failings in mine closure practice in South Africa were expounded, inter alia: weak senior management commitment, poor baseline studies, an unstable legislative milieu, the quality of environmental monitoring data, the existence and practicability of mine closure plans and misalignment between government, mining houses and communities. Nevertheless, numerous successes were also enumerated including a focus on ‘mining for closure’ by implementing proactive planning, particularly regarding end use objectives for water and land. Thus, linking sustainability principles, objectives of closure, and with a view to addressing the gaps in South African closure practice, this study proposes an environmental sustainability indicator framework in an effort to afford the mining industry a tool to measure (and manage) the trajectory of a mine’s operations toward sustainable closure. Furthermore, a conceptual framework which iteratively guides sustainable mine closure is put forward; and the stabilisation of the mining legislation milieu in South Africa is also strongly advocated as an imperative in encouraging and achieving such lasting closure.
<table>
<thead>
<tr>
<th>CHAPTER 2: LITERATURE REVIEW</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction</td>
<td>7</td>
</tr>
<tr>
<td>2.2. The South African Context, Mining and Minerals</td>
<td>7</td>
</tr>
<tr>
<td>2.2.1 Introduction</td>
<td>7</td>
</tr>
<tr>
<td>2.2.2 South African Mineral Resources</td>
<td>7</td>
</tr>
<tr>
<td>2.2.3 The Economics of the South African Mining Industry</td>
<td>8</td>
</tr>
<tr>
<td>2.2.4 Coal</td>
<td>10</td>
</tr>
<tr>
<td>2.2.4.1 Acid Mine Drainage</td>
<td>12</td>
</tr>
<tr>
<td>2.2.5 Gold</td>
<td>13</td>
</tr>
<tr>
<td>2.2.6 Platinum</td>
<td>15</td>
</tr>
<tr>
<td>2.2.7 Diamonds</td>
<td>16</td>
</tr>
<tr>
<td>2.2.8 Rationale for Reviewed Minerals</td>
<td>17</td>
</tr>
<tr>
<td>2.2.9 Conclusion</td>
<td>20</td>
</tr>
<tr>
<td>2.3 Sustainable Development Principles in Mining</td>
<td>20</td>
</tr>
<tr>
<td>2.3.1 Introduction</td>
<td>20</td>
</tr>
<tr>
<td>2.3.2 The Initial Conception and Evolution of Sustainable Development</td>
<td>21</td>
</tr>
<tr>
<td>2.3.3 The International Mining Sector’s Responses to Sustainable Development</td>
<td>22</td>
</tr>
<tr>
<td>2.3.3.1 The GMI</td>
<td>23</td>
</tr>
</tbody>
</table>
2.3.3.2 The MMSD Project..............................................................................................................23
2.3.3.3 The JPOI ..........................................................................................................................27
2.3.3.4 Berlin II – Guidelines for Mining and Sustainable Development .........................28
2.3.3.5 The EIR ............................................................................................................................29
2.3.3.6 The GRI and The Mining and Metals Sector Supplement........................................30
2.3.3.7 Framework for Responsible Mining ..............................................................................31
2.3.3.8 Enduring Value: The Australian Minerals Industry Framework for Sustainable Development.................................................................32
2.3.3.9 BellagioSTAMP: Sustainability Assessment and Measurement Principles .......33
2.3.3.10 Balancing Mining and Sustainable Development – APEC Report .................33
2.3.3.11 International Finance Corporation (IFC) Sustainability Framework and Performance Standards and IFC & World Bank Environmental, Health and Safety Guidelines for Mining..................................................................................................................34
2.3.3.12 Equator Principles........................................................................................................35
2.3.3.13 The Mining Association of Canada - Towards Sustainable Mining.....................37
2.3.3.14 A Mining Policy Framework .......................................................................................38
2.3.3.15 Responsible Mineral Development Initiative (RMDI) .................................................39
2.3.3.16 Conclusion ....................................................................................................................39
2.3.4 The Impact of Sustainable Development Policy on South Africa and its Mining Sector .................................................................................................................................40
2.3.5 Conclusion: Sustainable Development Principles and Modes ..................................43

2.4 Mining Methods and Mine Closure .................................................................................46
2.4.1 Mining Methods .................................................................................................................46
2.4.1.1 Historical Mining Methods ..........................................................................................46
2.4.1.2 Underground Mining Methods ....................................................................................47
  2.4.1.2.1 Board and Pillar ..................................................................................................47
  2.4.1.2.2 Longwall ..........................................................................................................48
  2.4.1.2.3 Stoping ..............................................................................................................49
  2.4.1.2.4 Caving ................................................................................................................50
  2.4.1.2.5 Underground Mining Environmental Impacts ...................................................51
2.4.1.3 Surface Mining Methods .............................................................................................51
  2.4.1.3.1 Strip Mining ......................................................................................................51
  2.4.1.3.2 Terrace Mining .................................................................................................52
<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4.1.3.3 Open Pit Mining</td>
</tr>
<tr>
<td>2.4.1.3.4 Alluvial and Shore Mining Methods</td>
</tr>
<tr>
<td>2.4.1.3.5 Surface Mining Environmental Impacts</td>
</tr>
<tr>
<td>2.4.1.4 Waste Dumps and Tailings</td>
</tr>
<tr>
<td>2.4.2 Mine Closure</td>
</tr>
<tr>
<td>2.4.2.1 Environmental Impacts and Objectives of Closure</td>
</tr>
<tr>
<td>2.4.2.2 Mine Closure in South Africa</td>
</tr>
<tr>
<td>2.5 Sustainable Development Indicators</td>
</tr>
<tr>
<td>2.5.1 Indicators of Sustainable Development</td>
</tr>
<tr>
<td>2.5.2 Practical Considerations of Indicators</td>
</tr>
<tr>
<td>2.5.3 Considerations in Formulating an Indicator Set</td>
</tr>
<tr>
<td>2.6 South African Mine Closure Legislation</td>
</tr>
<tr>
<td>2.6.1 Introduction</td>
</tr>
<tr>
<td>2.6.2 The Mineral and Petroleum Resources Development Act</td>
</tr>
<tr>
<td>2.6.3 Other Applicable Legislation</td>
</tr>
<tr>
<td>2.6.4 Conclusion</td>
</tr>
<tr>
<td>2.7 Conclusion</td>
</tr>
<tr>
<td>2.7.1 A Synthesis: The Intersection of Sustainable Development Policy, Mine Closure and Indicators</td>
</tr>
</tbody>
</table>

**CHAPTER 3: METHODOLOGY** ................................................................. 70

<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
</tr>
<tr>
<td>3.2 Questionnaire Design and Distribution</td>
</tr>
<tr>
<td>3.2.1 Questionnaire Design Theory</td>
</tr>
<tr>
<td>3.2.2 Questionnaire Tailoring</td>
</tr>
<tr>
<td>3.2.3 Garnering Respondents</td>
</tr>
<tr>
<td>3.2.4 Electronic Web-based Questionnaire Design</td>
</tr>
<tr>
<td>3.2.5 Distribution, Follow Up and Responses</td>
</tr>
<tr>
<td>3.2 Conclusion: Questionnaire Analysis</td>
</tr>
</tbody>
</table>
CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

4.2 Respondents’ Experience and Work Environments

4.2.1 Sectoral Analysis

4.2.2 Mineral Type Analysis

4.2.3 Mine Closure Cycle Experience

4.3 Status Quo of Mining Environmental Indicators in South Africa

4.3.1 Baseline Environmental Indicators

4.3.2 Current Operational Environmental Indicators

4.3.2.1 Specific Operational Indicators

4.3.2.2 Operational Indicators Found to be Lacking

4.3.3 Environmental Indicators Beyond the Mine Site Boundary

4.3.4 Do Environmental Indicators Relate to Final Land Use?

4.3.5 Ideal Environmental Indicators

4.4 Mine Closure and Closure Planning

4.4.1 The Existence of Mine Closure Plans and Closure Reporting

4.4.2 Imperative Investigations for Mine Closure

4.4.3 Is There Successful Mine Closure in South Africa?

4.5 Discussion of Challenges and Successes of Mine Closure in South Africa

4.5.1 Successes

4.5.2 Challenges

4.6 Awareness and Opinions of South African Mine Closure Legislation

4.6.1 Awareness of South African Mine Closure Legislation

4.6.2 Experts’ Opinions on South African Mine Closure Legislation

4.7 Conclusions

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

5.2 Identified Gaps Between Policy, Legislation and Closure Practice

5.3 Recommendations

5.3.1 An Indicator Framework Developed to Address the Gaps Between Mining Sustainability Policy and Current Mine Closure Practice in South Africa
5.3.2 Other Recommendations ................................................................. 111
5.4 Success of Meeting Initial Research Objectives .................................. 113
5.5 Suggestions for Further Research ....................................................... 115

REFERENCES ................................................................................................. 116

APPENDICES .................................................................................................. 136

Appendix A: Master Questionnaire ............................................................... 137
Appendix B: Applicable Mine Closure Excerpts from South African Legislation .... 138
      Regulations .................................................................................................. 141
LIST OF FIGURES

Figure 1: Historical South African gold production ............................................................... 13
Figure 2: An adit mine ............................................................................................................ 46
Figure 3: Placer deposits ......................................................................................................... 47
Figure 4: Underground board and pillar mining ................................................................. 48
Figure 5: Underground longwall mining ............................................................................. 49
Figure 6: Underground stoping with cut and fill ................................................................. 50
Figure 7: Terrace mining ........................................................................................................ 52
Figure 8: Cross section of an open pit mine ........................................................................... 53
Figure 9: Phases of a mine life cycle with consideration given to sustainable closure
throughout .................................................................................................................................. 56
Figure 10: Closure consequences of good vs. poor life of mine planning and practices ..... 57
Figure 11: Venn diagram representing the key elements of this study .................................. 69
Figure 12: Respondents by sector (Percentage) .................................................................... 79
Figure 13: Respondents’ closure experience by mineral (Percentage) ................................. 80
Figure 14: A generalised conceptual framework which iteratively guides sustainable mine
 closure ................................................................................................................................... 112

LIST OF TABLES

Table 1: Minerals reviewed in this study .............................................................................. 18
Table 2: Environmental impacts of minerals reviewed in this study ..................................... 19
Table 3: Consolidated list of principles derived from major international ‘sustainable
development in mining’ initiatives and corresponding South African policy ....................... 44
Table 4: Benefit analysis of freely available web-based survey tools .................................... 74
Table 5: Respondents’ breadth of mine closure experience .................................................. 82
Table 6: Consolidated baseline indicators and studies provided by South African mine closure
practitioners .............................................................................................................................. 86
Table 7: Respondents’ awareness of the four extracts of closure legislation ......................... 102
Table 8: The ratification of sustainability principles in South African legislation and the
shortcomings of the ‘on-the –ground’ implementation thereof ............................................. 106
Table 9: An environmental sustainability indicator framework to address the gaps between
mine closure sustainability policy and current mine closure practice in South Africa ........... 109
Table 10: Summary of the fulfilment of research objectives ................................................ 114
LIST OF ACRONYMS

AMD – Acid Mine Drainage
APEC – Asia-Pacific Economic Cooperation
CGS – Council for Geoscience
CSD – Commission on Sustainable Development
CSP2 – Centre for Science in Public Participation
DEA – National Department of Environmental Affairs
DME – National Department of Minerals and Energy
DMR – National Department of Mineral Resources
DWA – National Department of Water Affairs
DWAF – National Department of Water Affairs and Forestry
EIA – Environmental Impact Assessment
EIR – Extractive Industries Review
EMP – Environmental Management Plan
EMS – Environmental Management System
GDP – Gross Domestic Product
GHG – Greenhouse Gas
GMI – Global Mining Initiative
GN – Government Notice
GRI – Global Reporting Initiative
ICME – International Council on Metals and the Environment
ICMM – International Council on Mining and Metals
IFC – International Finance Corporation
IGF – InterGovernmental Forum on Mining, Minerals, Metals and Sustainable Development
IISD – International Institute for Sustainable Development
IUCN – International Union for Conservation of Nature
JPOI – Johannesburg Plan of Implementation
MAC – Mining Association of Canada
MMSD – Mining, Minerals and Sustainable Development
MPRDA – Minerals and Petroleum Resources Development Act
Mpta – Million tons per annum
MVM – Mineral Value Management
NEMA – National Environmental Management Act
NEMAQA – National Environmental Management: Air Quality Act
NEMLAB – National Environmental Laws Amendment Bill
NFSD – National Framework for Sustainable Development
NGO – Non-Governmental Organization
NSSD – National Strategy for Sustainable Development
OECD – Organisation for Economic Co-operation and Development
PGMs – Platinum Group Metals
PM10 and 2.5 – Particulate Matter 10μm and 2.5μm
RBCT – Richards Bay Coal Terminal
RDMI – Responsible Mineral Development Initiative
RSA – Republic of South Africa
SDM – Sustainable Development through Mining
TDS – Total Dissolved Solids
TSM – Towards Sustainable Mining initiative
UN – United Nations
WBCSD – World Business Council for Sustainable Development
WEF – World Economic Forum
WRI – World Resources Institute
WSSD – World Summit on Sustainable Development
CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO RESEARCH

South Africa is a mineral rich country with a long established mining sector (Hoadley et al, 2002; GDACE, 2008). With the worldwide advent of the discourse around and conscious need to practice sustainable development, mining has needed to be framed and tackled from a sustainable development perspective (WSSD & UN, 2002; Nzimande & Chauke, 2012). By its very nature mining of a finite ore body is a temporary land use (Absolom & Limpitlaw, 2005; Robertson & Shaw, 2005). Upon reaching the end of viable economic production, a mine will need to be ‘closed’. Historically, closure has been environmentally inept leaving lasting negative consequences. With modern sustainable development principles driving mining practice, these negative impacts should be ameliorated upon closure; whereby mine closure should contribute positively, leaving a sustainable land use legacy for future development. However in practice, closure is often poorly planned for with near on unmitigateable environmental impacts remaining (DMR, 2009).

The research problem stems from an interest in sustainable development and its seemingly paradoxical relation to the environmental legacy of mine closure (Kirch, 2010).

On the whole, closed mines continue to generate environmental hazards such as acid mine drainage (AMD), the associated mobilization of heavy metals, decreased soil fertility, surface instability and airborne PM10 dust; in some cases almost indefinitely (Cottared, 2001; GDACE, 2008; van Tonder et al, 2009; McCarthy, 2011). Closed mines also tend to obviate useful future land use to the detriment of the ecosystem functioning and human health and prosperity (Robertson & Shaw, 2005). These consequences, along with others, are diametrically opposed to the tenet of sustainable development most often defined (Pavlovskia, 2013) by its original coining in the Brundtland Report as: “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” (UNWCED, 1987).

South Africa subscribes to the principle of sustainable development throughout its governance framework; principally through it being enshrined in Section 24 of the South African Constitution (1996):

-Everyone has the right-

(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that-

(i) prevent pollution and ecological degradation;
(ii) promote conservation; and
(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Accordingly, South Africa is committed, as exemplified in the Mineral and Petroleum Resources Development Act (MPRDA) (DME, 2002) and National Environmental Management Act (NEMA) (DEAT, 1998) amongst others, to addressing mine closure and its associated environmental consequences in a manner which promotes sustainable development (DWAF, 1999; UN, 2002a; DEAT, 2003; Danielson, 2006; DME, 2007; DME, 2008; DEA, 2011; Nzimande & Chauke, 2012). This seeming antithesis between mining’s environmental consequences and sustainable development principles, thus begged the question: how is progress toward or away from the environmental component of sustainable development measured with respect to mine closure?

South Africa has “in excess of five thousand ownerless and derelict mines” (DME, 2007: 63), whose estimated liability to the state is R1.6 billion over 10 years, but ultimately would require a conservative estimate of R30-billion for environmental restoration (Baartjes & Gounden, 2012). This is notwithstanding those closed mines, with owners, which are under varying levels of care and maintenance. Thus a set of environmental indicators which would support/facilitate sustainable mine closure in South Africa is very pertinent. Following on from this, the aim of this research would be: to determine if a set of environmental sustainability indicators can be compiled to support sustainable mine closure in South Africa.

There is apparently little research in the sector which covers the three interrelated themes which this study seeks to investigate, namely: sustainable development, environmental sustainability indicators and mine closure; all within the context of South Africa. From the investigation of the intersection of these themes, it is intended that a framework of environmental indicators with the aim of sustainable mine closure be arrived at. With such a framework, mining operations may chart their progress as they approach closure in terms of sustainable development. Thus, if management actions are fundamentally informed by these environmental mine closure indicators which are aligned with sustainable development, the resulting mine closure ought to prove sustainable.
1.2 AIM, OBJECTIVES AND METHODOLOGY OF RESEARCH

At the outset of this research, the following aims, objectives and methodology were set out to guide and frame the research. They are detailed as follows below.

The aim of this research is:
To develop a theoretical framework of environmental sustainability indicators which will measure progress towards sustainable development with respect to mine closure.

The aforementioned aim of this research shall be achieved through completing the following set of sequential objectives:


(ii). Evaluate South African mine closure legislation against aforementioned environmental principles and indicators of sustainable development.

(iii). Survey current mining industry best practice in South Africa, with respect to the support of sustainable closure by means of environmental indicators founded in sustainable development.

(iv). Define the gap between South African mince closure legislation (ii) and the South African mine closure status quo (iii), within the context of sustainable development principles (i).

(v). Propose a theoretical framework of environmental sustainability indicators to address the gap defined above (iv).

To achieve the objectives (i) through (v) mentioned in above, the following methodologies (a, b, c...) are proposed for each objective:

To achieve objective (i):

(a). Conduct a literature review to establish current global and South African best practice regarding environmental principles and indicators of sustainable development in mining.

To achieve objective (ii):

(a). Conduct a literature review to determine the extent of South African legislation which pertains to mine closure.

(b). The results of this South African mine closure legislation review (ii)(a) will be compared to the review of world and South African sustainable development principles and environmental indicators in mining (i)(a).

(c). With the comparative knowledge gained in (ii)(b), the sustainable development principles and environmental indicators embedded in South African legislation will be documented and made explicit.
To achieve objective (iii):

(a). Draft a pertinent survey based on learnings from (i) and (ii). This will seek to question what the South African mining industry is seeking to achieve, and how are they going about it, with respect to environmental indicators, mine closure and sustainable development.

(b). The survey compiled in (iii)(a) will then be circulated to relevant mining professionals/experts.

(c). Based upon the responses to the survey conducted in (iii)(c), a summary of the status quo regarding environmental indicators, mine closure and sustainable development in South Africa will be detailed.

To achieve objective (iv):

(a). Perform a gap analysis, in the context of sustainable development principles (i), between the practice ‘on-the-ground’, based on the results of the survey (iii)(c), and the legislative closure requirements as defined by (ii)(c).

To achieve objective (v):

(a). Propose a set of environmental sustainability indicators which will seek to address the gap between, sustainable development principles and South African legislation, and the current status quo (as defined in (iv)).

1.3 LIMITS OF STUDY

This study will research and investigate the themes, topics, gaps and interrelationships between mine closure, sustainability and environmental sustainability indicators within the context of South Africa. It takes cognisance of the global development of sustainable development, both as a broader concept and with respect to mining. This is done to better frame the ‘sustainable development and mining’ discourse within a South African context. Sustainable development has come to be viewed containing three principle elements operating within a governance context, namely, social, environmental and economic aspects. (WSSD & UN, 2002; DME, 2009) This study however primarily focuses on establishing indicators to measure the ‘environmental’ facet of sustainable development within the setting of mine closure. As such, the economic and social aspects do not receive prime attention, although they may be mentioned when relevant to the discussion. If, in the text, the exact nature/type of the impacts is not specified, it should be taken that the impacts referred to are environmental. Moreover, it must be noted that this study takes the stance of interrogating mine closure from a position of ‘strong sustainability’; defined by Neumeyer (2013) as being when: “natural capital is regarded as non-substitutable, [neither by] the production of consumption goods, its capacity to absorb pollution [nor] as a direct provider of utility in the form of environmental amenities”.

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This is in opposition to ‘weak sustainability’, which maintains that technological innovation and products are the solution to the environmental impacts of growth and that natural capital can thus be substituted for man-made capital (Davis, 2013).

With respect to mine closure, only certain key South African minerals are considered. Furthermore, only major mining methods are discussed in detail. As is justified in Section 2.2.8 and by Table 1, the primacy of these minerals and mining methods ensures a broad yet representative investigation. It must be noted that by the nature of policy publications regarding sustainability principles in mining, much of the literature in Section 2.3 is authored by institutions. Lastly, the study shall also be limited by the nature and detail of the responses received from experts in the South African mine closure industry who voluntarily completed the survey.

1.4 DESCRIPTION OF CHAPTERS

The chapters of this study are laid out in the generally accepted order of: Introduction, Literature Review, Methodology, Results and Discussion and Conclusions and Recommendations (Kallestinova, 2011).

Chapter 2: Literature Review, begins with providing the South African mining and minerals context, from which key minerals are highlighted. This is followed by an extensive review of international mining sustainability policy and the principles thereof, with particular reference to closure where possible. The integration of these principles into South African mining policy is subsequently discussed. The various methods of mining and the consequent environmental impacts of mine closure are detailed hereafter. This is followed by a review of literature on sustainable development indicators. The ratification of the aforementioned sustainability principles in South African mining and mine closure legislation is then discussed. The chapter concludes by synthesising the literature reviewed and discussing the intersection of sustainable development policy, mine closure and indicators so as to foreground the ultimate aim of measuring sustainable closure progress.

Chapter 3: Methodology, details the steps taken to conduct the research and data collection. This begins with an overview of questionnaire design and tailoring, and is followed by the means utilised to garner respondents with mine closure expertise in South Africa, and subsequently survey them using an online web-platform. The chapter concludes with a brief discussion of the manner in which the questionnaire responses were analysed.
Chapter 4: Results and Discussion, discusses and analyses the results of the questionnaire in terms of the major objectives of the questionnaire, viz.: respondent’s mine closure experience; the South African status quo with respect to baseline and operational environmental indicators, as well as mine closure and closure planning; South African mine closure successes and challenges; and lastly the awareness and opinions of these professionals of the South African closure legislation.

Chapter 5, Conclusions and Recommendations, synthesises the research and identifies gaps between policy, literature and the current South African status quo regarding mine closure. From this a framework of indicators is recommended to address the gap and direct mine closure toward sustainability. Furthermore recommendations are made regarding the integration of sustainability principles throughout the mine closure process, as well as recommendations regarding the problematic mining legislation milieu in South Africa. The initial research objectives are then revisited and the study is evaluated for its fulfilment of these objectives. The research is concluded with suggestions for further research. This is followed by a list of references cited and relevant appendices.
CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The literature reviewed covers the three broad aspects of this study, namely: sustainable development, mine closure and environmental indicators. All these topics are covered primarily within the sector of mining and at varying levels of application: global, regional and South African.

2.2. THE SOUTH AFRICAN CONTEXT, MINING AND MINERALS

2.2.1 Introduction

With a surface area of 1.2 million km$^2$, South Africa is richly endowed with mineral deposits including coal, iron, copper, gold, and platinum. Soils are generally thin and moderately fertile. The climate is typically warm and dry. Winter temperatures rarely fall below 0°C and summer maxima often exceed 35°C in certain parts. The average annual rainfall is only about 500 mm, making fresh water South Africa’s most limiting natural resource (van Rensburg & van Rensburg, 2012). Nevertheless South Africa is also one of the most biodiverse countries, occupying only 2% of the world’s surface area, yet housing almost 10% of the world’s plants and 7% of the world’s animals. Levels of endemism are high with the fynbos biome falling entirely within the country’s borders (DEAT, 2005). As of the 2011 national census, the total population was 51.7 million people. Poverty and inadequate education are major problems with only 28.4% of the population over 20 years having completed high school and an additional 12.1% having a tertiary education, while 8.6% have no education whatsoever and the balance (50.9%) only partial education (StatsSA, 2012a). The current national unemployment rate stands at 25.2%, and people residing in informal housing at 13.6% (StatsSA, 2014).

2.2.2. South African Mineral Resources

South Africa’s modern raison d’être could be said to be mining; so significant has it been historically, economically, socially, politically and environmentally. Globally, South Africa has the largest resource base of: gold, platinum group elements, chrome and manganese. Furthermore South Africa is the largest producer and/or exporter of alumino-silicates, ferro-chromium, ferro-silicon, vanadium and vermiculite. It is also a top-ten producer of: diamonds, antimony, coal, fluorspar, iron ore, lead, silicon, titanium and zirconium minerals, vanadium and uranium. All these are major economic minerals in industries as wide ranging as pharmaceuticals, electronics, power generation, chemical production, building materials,
automotive fabrication and agriculture. Gold was previously the keystone to the South African economy, but has diminished in importance as reserves are dwindling and ever deepening gold seams are increasingly difficult to mine (World Bank & IFC, 2002; COMSA, 2011). Off-shore mining in South Africa is also relatively productive. The near shore and shelf environments of the west coast hold rich reserves of minerals, particularly diamonds, and in South Africa there is an increasing emphasis on offshore diamond mining operations. At present marine diamonds comprise about 10% of South Africa's total diamond production. The west coast also supports oil mining, although South Africa’s exploration for oil is focussed on the south east coast (DEA, 2010a). To give further perspective on the extent of mining in South Africa, in 2005, there were some 55 economic minerals produced from some 1113 mines in South Africa. Mining methods vary from opencast strip mining, underground 'board and pillar' and longwall techniques; to alluvial, offshore, artisanal and dune mining operations (DEA, 2010a). Further beneficiation of the ore/mineral is also significant, with most ‘Run of Mine’ product being subject to a secondary beneficiation process (COMSA, 2011). Thus mining is a complex, entrenched and far reaching activity in the socio-economic fabric of South Africa, with significant attendant impacts on the natural environment (Singer, 2011).

2.2.3 The Economics of the South African Mining Industry

In 2010, according to the South African Chamber of Mines, the mining sector accounted for 8.6% of the country’s Gross Domestic Product (GDP). At the forefront, gold, platinum group metals (PGMs) and coal contributed 71% of total mineral sales in 2009 (StatsSA, 2012b). Taking into account indirect multiplier effects and spin-off industries and services, the total contribution to GDP is estimated at around 19%. In the context of exports, mineral sales totalled R224.2-billion in 2010, which represented 35.9% of the country’s total merchandise exports. This figure increases to approximately 50%, if secondary beneficiated minerals are added to primary exports, for example, PGM catalytic converters, ferro-alloys, steel, chemicals, and plastics (COMSA, 2011).

In its 2010 report, Facts and Figures, the Chamber of Mines goes on to state that of the mining sector’s R441-billion expenditure that year, R78.4-billion was paid in salaries and wages, R49-billion on capex projects, R17.1-billion in tax and R16.2-billion in dividends. According to its estimates, only 8% (R34-billion) of total expenditure was moved offshore. Hence 92% of the value of local mining expenditure is captured in South Africa; a figure which is contrary to some conceptions of mining’s business operations. This results in the creation of half a million direct jobs, or 8% of South Africa’s total private non-agricultural employment (COMSA, 2011). The economic multiplier and spin-off effects into secondary industries are substantial. Nearly 100% of building materials and aggregates are produced locally; 80% of the steel used in the country is manufactured in South Africa from locally mined iron ore, chrome, manganese and coking coal; local coal mining provides fuel for 95% of all electricity generation and 30%
of the country’s liquid fuels are produced from the liquefaction of local coal. Further to this, South African mining provides the raw materials for the domestic manufacture of chemicals, fertilisers, waxes, polymers and plastics as well as the platinum for the local manufacture of 20% of the world’s catalytic converters. All PGM’s and gold are refined in South Africa, and 50% of mined diamonds are cut and polished by local industry. With these local downstream beneficiation industries taken into account, the Chamber of Mines estimates an additional 150 000 jobs are created generating another R200-billion in sales in 2010 (COMSA, 2011).

These figures go to show the significance of mining in a developing economy like South Africa’s where the official unemployment rate stands at 24.1%, and the absorption rate (proportion of working-age population employed) at 43.3% (StatsSA, 2014). Thus, those who are in fact employed within the mining sector, a labour intensive activity and therefore requiring of high numbers of lower waged unskilled and semi-skilled labour, are likely to support numerous unemployed dependants. In the ‘developing’ country context that South Africa finds itself in, this economic dependency alone justifies the continuation of mining as an activity of national importance. This historical and now ‘matter-of-fact’ dependency has however given rise to certain social and environmental problems. As Limpitlaw (2004a: 2) states: “two crucial components of sustainable development [are]: poverty alleviation and environmental stewardship. The interaction between these two components lies at the heart of the challenge facing the minerals industry in Southern Africa.”

Despite South Africa’s climb in the 2012 Survey of Mining Companies, released by Canada’s Fraser Institute, the country remains a hotbed of political mining debate, with enduring issues surrounding legislation, nationalisation and labour conflicts (McMahon & Cervantes, 2012). The country was ranked 67th out of 79 mining jurisdictions in 2011, and climbed to 54th out of 93 for 2012. As one of the world’s most resource-rich countries, however, this ranking is far below its potential, and the South African Institute of Race Relations has pointed out that uncertainty over nationalisation and mine ownership, and increasing work disruptions, are affecting investors’ willingness to look into mining ventures in the country and have made the country a significantly less attractive mining investment destination since 2006 (Greve, 2012).
2.2.4 Coal

South Africa produces coal for both local and export markets. It ranks within the top ten producers by volume in the world, and produced 245 million tons of saleable coal in 2010. It is also ranked sixth in the world with respect to proven reserves (StatsSA, 2012b). Of the coal produced, 96% is low to medium grade bituminous coal, with a high ash content but usually low sulphur content, for electricity generation. All export coal, comprising the higher qualities, is rail freighted to Richards Bay Coal Terminal (RBCT), the largest such terminal in the world with a capacity of 91 Million tons per annum (Mpta). In 2011, coal exports totalled 65.5 million tons (Kohler, 2012). The other three quarters of the coal produced and consisting of lower grades, is sold for domestic use, primarily as steam coal (~70% thereof, for electricity generation), liquid fuel production (~20% thereof, by coal liquefaction), with the remaining ~10% used for coking coal (steel production) and low income domestic fuel burning (Conti et al, 2013). Despite falling behind countries like China, USA and India in terms of production; and Australia, Indonesia, Russia and Colombia being larger exporters, South Africa is a low cost producer due to the nature of the labour market and the relatively shallow, thick seams; it is also well positioned to service both Asian and European markets, and hence remains a competitive supplier. South Africa has some of the largest estimated reserves in the world; in the 1980’s recoverable reserves were estimated 59.24-billion tons. Present reserves are estimated at between 28-billion tons and 33-billion tons. Current operations are focused in the Mpumalanga province in the Central Basin (which includes the Witbank, Ermelo and Highveld coalfields), with the Free State coalfield also under significant production. However, these current coaling operations are expected to peak in the next decade, with the consequent road to closure the ultimate path (Eberhard, 2011; Kohler, 2012).

In 2010, South Africa accounted for 93% of the entire African continent’s coal consumption, and more than 90% of the country’s electricity is generated by the burning of coal (Edkins et al, 2010; Eberhard, 2011). With electricity demand outstripping supply circa 2008, South Africa’s parastatal power utility, Eskom, has embarked on a capacity development program which is still primarily coal-fired based. The Waterberg coal corridor in Limpopo province has thus recently come into focus as a new coalfield to be developed as mandated in the South African National Infrastructure Plan, designated Strategic Integrated Project #1: Unlocking the northern mineral belt with Waterberg as the catalyst (PICC, 2012, SACRSC, 2013). However, the Waterberg coal field has significant challenges: the coal is of a low grade, interbedded with shales and siltstones leading to a high ash content; it is positioned a substantial distance from markets, with low levels of infrastructure to facilitate mine development and product transport; and most notably the area is water scarce which is a hindrance to mine development and product beneficiation while constituting substantial potential negative environmental impacts (Kohler, 2012).
Nevertheless, it has been estimated that as of 2009, another 121 years of proven coal reserves remain in South Africa (StatsSA, 2012b). With this significant coal resource base, increases in South Africa’s population and electricity demand, the socio-economic upliftment goals of job creation and service delivery, the attendant motivations of economic development and the existing, planned and under-construction coal-fired power stations, coal mining and production remains a priority strategic resource to South Africa (DMR, 2011).

However, the mining of coal entails significant alteration of the environment, with resultant negative impacts, which also often culminates in long term cumulative and regional impacts. These include, inter alia (Keating, 2001; Munnik et al, 2010; Castleden et al, 2011; Lutz et al, 2013):

- **Air pollution:** Dust particulates (PM10 and PM2.5); spontaneous combustion of coal both underground and of discard dumps; emissions of greenhouse and other noxious gases: CO$_2$, NO$_x$, SO$_x$, O$_3$, H$_2$S, methane, benzene and other organic compounds.
- **Land use:** Loss of topsoil and reduced alternative land uses (e.g. agriculture); surface subsidence; increased erosion and flood risk; overburden and tailings waste dumps; abandoned pits and shafts.
- **Water pollution:** decant of Acid Mine Drainage (AMD); increased Sulphate and Total Dissolved Solids (TDS) loads (salination); mobilisation of heavy metals due to AMD; increased sedimentation; leachate from discard dumps; alteration of surface and underground water systems (aquifers, rivers, wetlands) and water balance disruption; increased water consumption for beneficiation; contribution to acid rain.
- **Ecosystem disturbance:** habitat destruction and fragmentation; vegetation clearing (opencast); biodiversity losses.
- **Other:**
  - Waste dumps: slumping, ineffective rehabilitation, leaching, dust generation, erosion and siltation, permanent footprint and difficult to repurpose.
  - Noise and vibration: from blasting, mining equipment and mining and processing activities.
  - Accidental chemical release: petrochemicals, explosives and hazardous waste.
  - Increased resource use: of water, electricity, fossil fuels etc.
  - Visual: associated with the alteration of the natural landscape.

The severity of coal mining’s impacts are highlighted by the fact that in terms of the National Environmental Management: Air Quality Act (DEAT, 2004), the Witbank coal mining area has been declared as an ‘air quality priority area’ requiring active interventions to address air pollution in the area. This is primarily due to coal mining, coal transport and coal combustion in power stations (Munnik et al, 2010). Furthermore there is a focus on AMD in the area due to water shortages in the Olifant’s Catchment, which has led to the costly construction of water treatment plants (Manders et al, 2009; McCarthy, 2011).
2.2.4.1 Acid Mine Drainage

Acid mine drainage (abbreviated to AMD and also known as Acid Rock Drainage) is a well-studied phenomenon and its origins are well understood. The primary mineral responsible for AMD, and found in either the host rock or the ore itself, is iron disulphide or pyrite: FeS\textsubscript{2}. In the course of mining, between dewatering and underground mining operations, the blasting and crushing of the ore and storage of waste rock in tailings dams, pyrite comes in contact with oxygenated water. It is thus oxidised (either chemically or by biologically iron-oxidising bacteria such as \textit{Gallionella ferruginea}) in a two stage process: firstly, producing sulphuric acid and ferrous sulphate; and the secondly, orange-red ferric hydroxide and further sulphuric acid. In South Africa, pyrite is found within the mineralogies of the coal and gold geologies (Johnson & Hallberg, 2005).

This acidic water acidifies groundwater resources and ultimately surface water courses as well. Due to the low pH of the water, the solubility of aluminium and heavy metals in the environmental or tailings sediments is increased. The mobilisation of these metals in water resources is toxic to varying degrees. In due course, due to various factors (buffering potential of host geology, dilution within water resource or reaction with river sediments), the water is neutralised. However the associated sulphates, which are highly soluble, remain and contribute to the salt load of the water. Not all of South Africa’s mineral deposits have acid generation potential: the mine wastes of diamond, iron, manganese, chrome and vanadium mines are not acid-producing and neither is the majority of South Africa’s platinum mining (McCarthy, 2011).

Basic treatment practice of AMD in South Africa has been to add lime thereby raising the pH, while also blowing oxygen into the water to oxidise the iron, which then precipitates out with most of the other heavy metals. This iron and heavy metal precipitate is then separated out and disposed onto tailings dumps, while the ‘treated’ water is released into local rivers. However this treatment neglects the very high sulphate concentration (about 1500 mg/L) and hence the increases in the salt load on surface water resources (McCarthy, 2011). Ultimately the pyrite in these mining areas will be completely oxidised and AMD will cease being produced; however this is likely to take centuries (Younger, 1997; Rose, 2013).

Coal is thus a mature resource in South Africa. The Mpumalanga coalfields will in the near future enter decline, the Waterburg coalfield is anticipated to be developed and for the foreseeable future South African electricity generation is predominantly locked into coal with the current construction of the Kusile and Majuba power stations (Blignaut, 2012; PICC, 2012). With these factors considered in conjunction: the scale and time horizon of coal mining, and the associated negative and costly the environmental impacts, it is a necessity that sustainable mine closure in South Africa be realised.
2.2.5 Gold

80% of gold produced is used for jewellery, with the remainder used for ancillary technological purposes and coinage/investment (Guthrie, 2010).

The significant gold deposits in South Africa are concentrated in three geological settings, namely: the Archean, within greenstone-hosted deposits around Barbaton; the Black Reef conglomerate of the Transvaal Sequence, comprising quartz veins in sedimentary rocks and located in the East and West Rand as well as Pilgrim’s Rest and near Potchefstroom; and lastly the Witwatersrand Supergroup with its quartz-pebble conglomerates bearing disseminated gold. Despite the occurrence of gold in the area known aforehand, it was the particular rich discovery in 1886 of the Main Reef-Main Reef Leader outcrop in Langlaagte which triggered the Johannesburg gold-rush (Janisch, 1986). Thus the Witwatersrand goldfields, for a long time the world’s foremost producer of gold, have been in production for near on 130 years; however these goldfields are now in a ‘sunset phase’ with the resource depleted and becoming increasingly uneconomical to continue large scale exploitation. See Figure 1. Baartjies & Gouden (2012) attribute this to declining grades and difficulties associated with increased mining depths.

As is evident from Figure 1, South Africa’s Gold production peaked in 1970 at 1000 Metric tons; at this time this accounted for almost 80% of the world’s gold output. However in 2012 this share had dropped to 5.8%, with only 167 tons produced. According to the World Gold Council (2013), as of 2011, South Africa was ranked 5th in world gold production (7.02%); with a contribution of 2.45% to national GDP (Gross Domestic Product).
According to StatsSA (2012b), at the current rates of extraction, proven gold reserves are projected to last only another 30 years. Thus it can be noted that while gold still contributes significantly to the South African fiscus, it is no longer the ‘backbone of the economy’ that it once used to be. Gold mining is currently in a phase of decline as is clearly illustrated in Figure 1; this is widely accepted by the mining and academic community (Hartnady, 2009). This decline has however given rise to numerous social and environmental problems at this late/mature stage of the resource’s development.

Both the mining and processing of gold bearing ore have consequent environmental impacts. As with the impacts enumerate in the preceding section on coal, gold mining also results in: flooding, aquifer disruption and water pollution, particularly acid mine drainage (AMD) due to the exposure of sulphides (pyrite) to oxygen; airborne particulate matter from mine dumps; erosion; loss of land use; seismic activity/surface subsidence; accidental chemical spills and ecosystem disruption (Expert Team of the Inter-Ministerial Committee, 2010; Schueler et al, 2011). Guthrie (2010) highlights that in producing one ounce of gold, 20 - 33 tons of tailings are produced. Though spontaneous combustion (as with coal) is not an issue in gold mining, the heavy metals leached from tailings, and the chemicals used to recover the gold do present environmental issues. Due to the fact that the gold bearing ore must be milled very finely as part of the extraction process, the surface area is greatly increased. This liberates sulphides, which, reacting with oxygen and water, acidify the water. This drop in pH also mobilises numerous toxic heavy metals such as arsenic, cadmium, lead and mercury (Salami et al, 2003; Guthrie, 2010). This occurs both in tailings and waste dumps as well as the underground workings. Leaching, or decant from these acidified sources, spreads these contaminants to both surface and underground waters as is currently being experienced in the Witwatersrand basins (Manders et al, 2009; Expert Team of the Inter-Ministerial Committee, 2010). Furthermore, cyanide is commonly used in the commercial extraction process to liberate the disseminated gold from the ore and form an amalgam. The average large gold mine consumes 1900 tons of cyanide per annum. Cyanide is highly toxic (ingestion of one to three milligrams of cyanide per kilogram of body weight is fatal) and seepage from tailings dams and/or accidental spillages thereof is a significant environmental and human health risk. The integrity of such tailings dams should be monitored for seepage and structural failure constantly, long after operations have ceased (UNEP, 2000; Schaper & Aragao, 2014). The presence of uranium in gold bearing ore has also meant that upon mining, beneficiation and waste disposal, significant amounts of radioactive materials may accumulate in certain parts of the process (Wendel, 1998).

In artisanal (informal) mining, crushed ore is mixed with mercury to form an amalgam, which then being subjected to high heat, evaporates the mercury leaving an approximately 80% enriched gold sample. Murphy (2007), indicates that this toxic evaporated mercury is inhaled by the artisanal miners, deposited in the surrounding environment (contaminating water resources and bioaccumulating in fauna and flora), and it may circulate into the atmosphere where it may be eventually be deposited across the globe. Both Murphy (2007) and Guthrie
(2010) go on to state that 30% of the world’s anthropogenic mercury releases are from such artisanal mining methods.

Despite many South African gold mines being closed, or being near to closure; the impacts described above endure. Poorly rehabilitated, exposed mine dumps (evident across the Johannesburg Rand reef) continue to contribute to particulate air pollution (which may include carcinogenic elements) especially during the dry winter months, as well as the leaching of heavy metals and acidification of water. The same holds true for the underground mining voids where mining operations (and dewatering) have ceased: these underground basins fill up, acidifying recharge water and heavy metals are mobilised by the lowered pH. Underground aquifers, and surface water resources at decant points, are thus negatively impacted. Furthermore, the cumulative environmental impacts have become significant due to the interconnected nature of the old underground workings. This has become a topical and highly publicised regional issue in Gauteng province (Manders et al, 2009; Expert Team of the Inter-Ministerial Committee, 2010; Hamman, 2012).

2.2.6 Platinum

South Africa’s Bushveld Igneous Complex is host to the world’s largest reserves of Platinum Group Metals (PGM’s) and chromium. PGM comprises a ‘family’ of six chemically similar elements, namely: platinum, palladium, rhodium, ruthenium, iridium and osmium (StatsSA, 2012b). Platinum and palladium are the most abundant and valuable PGM’s, though platinum remains rarer than gold (Guthrie, 2010). Cawthorn (2010), with reference to numerous other studies, puts South Africa’s PGM reserve estimate at more than 80% of the world’s known deposits. StatsSA (2012b) further affirms that South Africa supplies nearly 80% of the world’s PGM’s. The occurrence of these PGM’s is within the geological setting of the Merensky, Platreef and UG2 reefs, and are concentrated in chromite and sulphide mineralisations (Cawthorn, 2010). This Bushveld Igneous Complex is located in the North-West and Limpopo provinces, and comprises three major limbs: the Western, Northern and Eastern limbs; these are located in the vicinity of Rustenburg/Thabazimbi, Potgietersrus and Steelpoort respectively (Cawthorn, 1999). With extraction assumed constant at 2009’s rate, proven PGM reserves are predicted to last 258 years (StatsSA2012b).

PGM’s are versatile and used in a wide array of technological applications, inter alia: catalytic convertors for reducing vehicle emissions, chemical catalysts for coating and for petroleum refining processes, fuel cell manufacture, electronic components including hard disks, glassmaking, jewellery, investment and coinage, medicines and dental alloys. Worldwide, demand remains strong and is even liable to increase considering the technological applications; for example in 2002, of the worldwide production of new passenger vehicles, more than 80% contained catalytic converters manufactured with platinum and/or palladium.
(Wilburn & Bleiwas, 2004). Wilburn & Bleiwas (2004) go on to note that the world PGM market is highly dependent on South African production due to its position as the world’s primary producer by a substantial margin; and as such, South African mining policy, labour disputes, production constraints, resource profitability and social and environmental issues affect the world’s PGM supply significantly.

According to Mudd (2010), mine waste and tailings constitute a most significant environmental aspect of platinum mining. With underground mines, 96-98% of the ore becomes tailings, and with the addition of overburden removal in opencast operations, 5 to 20 tons of overburden waste is removed to access every one ton of ore. The beneficiation process entails mixing a crushed platinum ore slurry with sulphuric acid and smelting it at >2700 °C. Thereafter, the resulting concentrate still contains nickel, copper and other metals, and requires further refining. This refining is a complex process that further uses: hydrochloric acid, nitric acid, ammonium chloride, and chlorine gas. Unlike gold mining and processing, platinum production also produces smelter slag and pollution which contain toxic dioxins (Guthrie, 2010). Aside from these platinum specific processes and contaminants, the environmental impacts are similar to coal and gold as described above: surface and underground topographical impacts, water resource consumption and system disruption, loss of land use and biodiversity, dust from tailings etc. However there is the notable exclusion of platinum mines producing AMD in most cases (McCarthy, 2011). Again, as with gold’s declining workforce, it must be noted that in platinum mining there are presently severe social concerns (Twala, 2012), but this is beyond the remit of this study.

2.2.7 Diamonds

Prior to 1870, the diamonds found in South Africa were alluvial. Upon discovery of diamonds in Kimberley, South Africa became the world’s largest diamond producer in terms of carats until as recently as 1993. The igneous rock (volcanic pipes) which is the primary source of diamonds was named kimberlite after the town (Damarupurshad, 2007). South Africa remains one of the world’s major producers ranking 4th both in terms of carats and in terms of value (Barradas, 2011). Diamonds in South Africa are still mined from all three source types: kimberlite (89%), alluvial (10%) and marine (1%) and continue to contribute significantly to the South African economy (see Table 1), which includes the downstream cutting, polishing and jewellery industry (DeBeers, 2014). Diamond has certain unique qualities. It is the hardest known material and has the highest thermal conductivity of any substance at room temperature. Diamonds are produced as either industrial or gem quality. Industrial diamonds are used in industrial cutting and polishing applications for their hardness and abrasiveness and may also be used for their optical and thermal conductivity properties, while gem quality diamonds are cut and polished for jewellery purposes (Hausel, 2006).
Open pit diamond mining is unremarkably dissimilar from open pit platinum mining which has already been discussed. The environmental impacts of alluvial mining however centre around the disruption of the watercourse: this comprises large scale in-stream excavation and the attendant destruction of habitat, flora, fauna, and river morphology; along with greatly increased erosion and consequent increased sediment loads. As with the afore mentioned minerals, there are also the associated impacts of dust from waste dumps, ecosystem fragmentation and loss of land use, increased flood risks, and increased resource consumption and contribution to greenhouse gasses. (Yelpaalaa & Ali, 2005).

2.2.8 Rationale for Reviewed Minerals

As has been detailed above, the mining sector is socio-economically significant in South Africa. However it does have the potential for substantial attendant environmental impacts. For instance Miranda et al’s (2003: viii) research indicates that: “More than one quarter of the world’s active mines and exploration sites overlap with or are within a 10-kilometer radius of a strictly protected area. Nearly one third of all active mines and exploration sites are located within areas of intact ecosystems of high conservation value. [Moreover] Nearly one third of all active mines are located in stressed watersheds.”

For this study gold, coal, platinum and diamonds have been selected as important minerals to review with regard to South African mine closure. They have certain differences as well as similarities, while all being mined on a substantial scale. Gold is in a declining phase of production after a long and prominent history; coal is a well-established ‘mature’ mineral and considered strategically important to the country’s electricity supply (DMR, 2011), with new reserves being explored; diamond production too is a stable and mature industry; and platinum though having been mined for some years, has the largest remaining reserves with global demand on an upward trend. All these minerals are mined by opencast and underground methods, yet gold and platinum are predominantly underground, with coal more frequently opencast, and diamonds additionally comprising an alluvial and coastal resource. Table 1 below summarises these prime considerations.

The mining of these minerals share many common environmental impacts, such as AMD generation, loss of land use, disruption of water resource systems (surface and underground), discard and tailings dumps and the fragmentation and destruction of habitat. They do however, as previously discussed, each have particular environmental impacts: coal spontaneously combusts creating additional air pollution impacts, gold and platinum’s mineralization and processing release heavy metals into the environment, diamond mining silts-up alluvial environments, and platinum’s refining produces additional toxic elements.

Table 2 summarises the environmental impacts in Sections 2.2.4 to 2.2.7. This selection of minerals seeks to provide a fair representation of significant environmental impacts arising
from intensive mining in South Africa and thereby validate the significance of addressing their legacy. With the exclusion of vanadium, this is supported by the following quote: “The country’s mineral industry can be broken down into five broad categories – gold, PGM, diamonds, coal and vanadium.” (StatsSA, 2012b: 1).

Table 1: Minerals reviewed in this study.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Platinum</th>
<th>Coal</th>
<th>Gold</th>
<th>Diamonds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government classification^</td>
<td>Strategic</td>
<td>Bulk</td>
<td>Precious</td>
<td>Precious</td>
</tr>
<tr>
<td>Mining Method</td>
<td>Underground</td>
<td>Opencast</td>
<td>Underground</td>
<td>Alluvial / Coastal</td>
</tr>
<tr>
<td>Lifecycle stage</td>
<td>Mid</td>
<td>Mid</td>
<td>Mature</td>
<td>Mid</td>
</tr>
<tr>
<td>Economic contribution 2011*</td>
<td>R 83.9b</td>
<td>R87.8b</td>
<td>R68.9b</td>
<td>Rough: R14.4b Polished: R23.6b</td>
</tr>
<tr>
<td>Production 2011*</td>
<td>151t</td>
<td>252.8Mt</td>
<td>191t</td>
<td>7m carats</td>
</tr>
<tr>
<td>Primary Risk Class #</td>
<td>B or C (Medium or Low) +</td>
<td>A (High)</td>
<td>A or B (High or Medium) +</td>
<td>B or C (Medium or Low) +</td>
</tr>
</tbody>
</table>

^ (DMR, 2011)
* (COMSA, 2012)
# (Naudé & Cornelissen, 2005)
+ The higher rating is assigned if the ore is also processed on the mine site. Underground mines have a minimum risk ranking of B.
Table 2: Environmental impacts of minerals reviewed in this study.

<table>
<thead>
<tr>
<th>Environmental Aspect</th>
<th><strong>Platinum (Underground)</strong></th>
<th><strong>Coal (Opencast)</strong></th>
<th><strong>Gold (Underground)</strong></th>
<th><strong>Diamonds (Alluvial/Coastal)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land</strong></td>
<td>Loss of land use; Surface subsidence; abandoned shafts</td>
<td>Loss of land use &amp; topsoil, increased erosion &amp; flood risk; abandoned opencast pit</td>
<td>Loss of land use; Surface subsidence; abandoned shafts</td>
<td>Loss of land use; Increased erosion &amp; flood risk</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>Disruption of streams &amp; aquifers &amp; water balance; increased sediment loads</td>
<td>Disruption of streams &amp; aquifers &amp; water balance; AMD; increased TDS, sulphate &amp; sediment loads</td>
<td>Disruption of streams &amp; aquifers &amp; water balance; AMD &amp; consequent heavy metals &amp; radioactivity; increased TDS, sulphate &amp; sediment loads</td>
<td>Disruption of streams and water balance; increased sediment loads</td>
</tr>
<tr>
<td><strong>Air</strong></td>
<td>Dust during operations and from waste rock &amp; tailings dumps.</td>
<td>Dust during operations and from waste rock &amp; tailings dumps.</td>
<td>Dust during operations and from waste rock &amp; tailings dumps.</td>
<td>Dust during operations and from waste rock &amp; tailings dumps.</td>
</tr>
<tr>
<td><strong>Ecosystem</strong></td>
<td>Fracturing &amp; destruction of habitat</td>
<td>Fracturing &amp; destruction of habitat; Vegetation clearing</td>
<td>Fracturing &amp; destruction of habitat</td>
<td>Fracturing &amp; destruction of habitat esp. riverine; Vegetation clearing</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Cumulative impacts; Waste dumps; Noise &amp; vibration; Accidental chemical spills; Visual; Increased resource use; Contribution to greenhouse gasses</td>
<td>Cumulative impacts; Waste dumps; Noise &amp; vibration; Accidental chemical spills; Visual; Increased resource use; Contribution to greenhouse gasses</td>
<td>Cumulative impacts; Waste dumps; Noise &amp; vibration; Accidental chemical spills; Visual; Increased resource use; Contribution to greenhouse gasses</td>
<td>Cumulative impacts; Waste dumps; Noise &amp; vibration; Accidental chemical spills; Visual; Increased resource use; Contribution to greenhouse gasses</td>
</tr>
</tbody>
</table>

* Primary method of mining.

(Sources: Sections 2.2.4 to 2.2.7)
2.2.9 Conclusion

Considering that ore is an economic concept (Hamrin, 1980), it is common practice to determine the feasibility of a mine based on its financial viability. This financial viability is estimated on the grade of the ore, the intensiveness of the mining method and the processing of the ore. However these three factors have enormous implications on the eventual closure of the mine. The mineralogy of the ore (linked to grade and impurities) directly affects any chemical processes which may take place upon the exposure of the ore to water and oxygen – which may result in the generation of certain pollutants. The mining method itself leaves a physical and topographical legacy which presents certain large scale closure challenges. And lastly, the mineral beneficiation may also give rise to waste dumps and pollutants which closure will need to address (Lainge & Trines, 2011).

Nonetheless, Needham (2002) estimates that only 5% of capital and operating costs for a new mining venture constitute expenditure on best practice. These costs are easily outweighed by mitigation of environmental accidents as well as efficiency savings in water and electricity for example. These environmental costs are most effective when incorporated at the planning stage, rather than retrofitting or accident remediation. This proactive approach translates into long term gains in terms of regulatory compliance and minimised environmental liability at the mine site. In considering the improvement of mining as a sector, consistently implementing such precautions and best practice facilitates access to land and mining licences, improves relationships with government and vested communities as well as minimising risk to the environment and leaving a positive legacy. Hence a proactive and precautionary approach by the mining industry towards the natural (and human) environment throughout the lifecycle of operations seeks to ensure the sector’s meaningful participation in sustainable development, and its own longevity.

2.3 SUSTAINABLE DEVELOPMENT PRINCIPLES IN MINING

2.3.1 Introduction

Since the advent of the catchall prerogative of sustainable development, the mining sector has sought to interrogate and integrate the evolving principles thereof into its operations. By the late 1990’s the mining industry was well aware of the new demands the burgeoning notion of sustainable development was placing on their current operating practices. Public, government and shareholder expectations linked to sustainable development were creating reputational risk, market reluctance regarding products, and even jeopardizing social license to operate in some instances. However, till this point, the mining industry’s responses to the imperatives of sustainable development had been fragmented and piecemeal (Danielson, 2006).
This section of the literature review seeks to investigate, through examination of policies and the history thereof, the evolution of the conception of sustainable development in mining and specifically highlight the principles inherent therein. In particular, once the broad global development of the concept and tenants of sustainable development have been discussed, a chiefly chronological account of major, multi-stakeholder sustainable development initiatives focused on mining follows. Each initiative’s origin, core aims, objectives, principles, reports and other pertinent information, particularly regarding mine closure, are described. This is followed by a discussion of sustainable development and mining within the South African discourse. The section culminates in a consolidated table of the ‘sustainable development in mining principles’ collated from the literature discussed.

2.3.2 The Initial Conception and Evolution of Sustainable Development

The evolution of the concept of sustainable development has an intricate but recent history. The first defining moment of sustainable development was preceded by the foundations laid down by the 1972 Stockholm Conference on the Human Environment (UN, 1972) and the 1980 World Conservation Strategy of the International Union for the Conservation of Nature (IUCN et al, 1980).

However the term sustainable development, as it is known today, was first coined by the Brundtland Commission in their report entitled Our Common Future, also known as the Brundtland Report (UNWCED, 1987: 27), which still serves as providing the most widely cited (Pavlovskiaia, 2013) definition of sustainable development, namely: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The report goes on to state that: “[Sustainable development] should become a central guiding principle of the United Nations, Governments and private institutions, organizations and enterprises, recognizing, in view of the global character of major environmental problems, the common interest of all countries to pursue policies aimed at sustainable and environmentally sound development, convinced of the importance of a reorientation of national and international policies towards sustainable development patterns.”

This concept of sustainable development was subsequently interwoven into successive and progressive treaties, conferences and research. Sustainable development came to be viewed as governing a sustainable balance between sustaining environmental systems, and developing/improving social and economic factors (Lélé, 1991).

The following milestone in the adoption and implementation of sustainable development was the Earth Summit in Rio de Janeiro five years later (June 1992). At this, the biggest international environmental conference convened to date, 100 heads of state were present and
30 000 participants. The major outcomes of this conference were international agreements, which included: the Convention on Biological Diversity, the Framework Convention on Climate Change (both of which were legally binding to signatories); Principles of Forest Management, the Rio Declaration on Environment and Development, and Agenda 21. The summit also led to the establishment of the UN Commission on Sustainable Development (Meakin, 1992; UN CSD, 2007). Agenda 21 in particular was an action plan for the implementation of sustainable development to which South Africa is a voluntary signatory. Agenda 21 recommended that states prepare national sustainable development reports using the structure of Agenda 21. These reports would be submitted to the Commission on Sustainable Development (CSD) and detail the activities undertaken to implement Agenda 21, the obstacles and challenges confronted in this respect, and other relevant environmental and developmental issues (Drexhage and Murphy, 2010). In 2000, The United Nations Millennium Declaration (UN, 2000) went further to define eight Millennium Development Goals for 2015 which were underpinned by the concept of sustainable development. Thus, it can be seen that the concept of sustainable development has been broadly integrated in international policy and goal setting.

2.3.3 The International Mining Sector’s Responses to Sustainable Development

By the late 1990’s the mining industry was well aware of the new demands the burgeoning notion of sustainable development was placing on their current operating practices. Public, government and shareholder expectations linked to sustainable development were creating reputational risk, market reluctance regarding products, and even jeopardizing social license to operate in some instances. However, till this point, the mining industry’s responses to the imperatives of sustainable development had been fragmented and piecemeal (Danielson, 2006).

Section 2.3.3 comprises a chiefly chronological account of major, multi-stakeholder sustainable development initiatives focused on mining. Each initiative’s origin, core aims, objectives, principles, reports and other pertinent information are described. In particular, the principles of sustainable development in mining are highlighted. The definition of a principle is: “A general law or rule adopted or professed as a guide to action; a settled ground or basis of conduct or practice; a fundamental motive or reason for action, esp. one consciously recognized and followed” (OED, 2014). Thus these principles are ‘rules’ which, if adhered to, bring into alignment the activity of mining and sustainable development (which ultimately culminates in sustainable closure). With the review highlighting such principles across multiple initiatives, the objective of this section is borne out in Section 2.3.5, in which the plurality of principles are collated and consolidated in Table 3. This is in fulfilment of objective (i) in Section 1.2. These consolidated principles are then used as a benchmark to conduct the gap analysis described in objectives (ii) and (iv).
2.3.3.1 The GMI

In January 1999, at the Annual Meeting of the World Economic Forum in Davos, Switzerland, the ten companies which made up the Mining and Minerals Working Group of the World Business Council for Sustainable Development (WBCSD), decided to form The Global Mining Initiative (GMI). The stated objective of the GMI was a leadership exercise aiming at: “reaching a clearer understanding of the positive role [that] the mining and minerals industries can play in managing the transition to sustainable development” (Danielson, 2006: 18). The GMI comprised three main facets:

1. The undertaking of the MMSD project (Mining, Minerals and Sustainable Development).
2. Resourcing the Future - A global conference on mining, metals and sustainable development (held in Toronto in May 2002).
3. The formation of the ICMM (International Council on Mining and Metals).

The MMSD project in particular, was a self-governing project, which was setup to include a broad spectrum of stakeholders, independent of industry, but with industry as an equal stakeholder. The MMSD sought, through transparent and regional multi-stakeholder consultation and evaluation, to ascertain how the mining industry’s role and operations could contribute to the global goal of sustainable development. The May 2002 Resourcing the Future conference then sought to convene these numerous stakeholders to discuss the final MMDS report and set a ‘way forward’. This was principally with the aim of contributing to the Earth Summit+10 in Johannesburg in September 2002. The ICMM, initially the ICME (International Council on Metals and the Environment), became the external body which represented the mining industry in the global arena of sustainable development discourse. Such a body was also deemed necessary to ensure buy-in to and implementation of the outcomes of the MMSD project (Danielson, 2006). The ICMM’s stated vision (ICMM, 2014a) is “Leading companies working together and with others to strengthen the contribution of mining, minerals and metals to sustainable development”.

2.3.3.2 The MMSD Project

Stemming from the aforementioned GMI, the Mining, Minerals and Sustainable Development project (MMSD) was a self-governing initiative, which was setup to include a broad spectrum of stakeholders, independent of industry, but with industry as an equal stakeholder. This influential and still relevant project sought, through transparent and regional multi-stakeholder consultation and evaluation, to ascertain how the mining industry’s role and operations could contribute to the global goal of sustainable development. Some 700 people from varied backgrounds in 20 countries attended the 23 global workshops which contributed toward the
study. The culmination and conclusion of the MMSD project was the 2002 report entitled *Breaking New Ground* (MMSD, 2002).

The MMSD report highlights the fact that all role-players in the minerals sector, inter alia: government, non-governmental organizations (NGOs), academic institutions, civil society, local communities, labour force, investors, insurers, and consumers, are required to play their part in driving the minerals sector towards the objective of sustainable development. Such a goal cannot be achieved in isolation by any one role-player; rather it requires a concerted effort at cooperation, from local through regional to global levels, to underpin successful sustainable development. The report acknowledges the four generally accepted spheres of sustainable development: Economic, Social, Environmental and Governance; and goes on to propose guiding principles for each within the framework of mining. In the context of this study, the environmental principles put forward are relevant, namely (MMSD, 2002):

1. Promote responsible stewardship of natural resources and the environment, including remediation of past damage.
2. Minimize waste and environmental damage along the whole of the supply chain.
3. Exercise prudence where impacts are unknown or uncertain. [The precautionary principle]
4. Operate within ecological limits and protect critical natural capital.

The Economic principle of identifying and internalising environmental (and social) costs is also notably relevant. Furthermore, throughout the report, and for each sphere, the underlying principle of subsidiarity was abided to. Subsidiarity “recognizes that decisions should be taken as close as possible to and with the people and communities most directly affected” (MMSD, 2002: xvii). Similarly ‘best practice’ is most effective when solutions are decentralized and within an iterative process, rather than top-down and once-off (MMSD, 2002). Of the numerous conclusions and recommendations that the 2002 MMSD report makes, it specifically suggests the collation of “a set of ‘must have’ generic, yet sector-specific indicators at the project and corporate level, supported by a secondary set of indicators that could be applicable at particular sites” (MMSD, 2002: xxxii). This is relatable to the objectives of this research.

On the basis of the MMSD report, in 2003 the ICMM adopted a charter of ten sustainable development principles. The ICMM committed its member companies (inter alia, AngloAmerican, Xtrata, Rio Tinto, BHP Billiton, Lonmin, Newmont, Barrick, and Goldfields) to implement and measure their performance against these ten sustainable development principles, namely (ICMM, 2014b):
1. Implement and maintain ethical business practices and sound systems of corporate governance.
2. Integrate sustainable development considerations within the corporate decision-making process.
3. Uphold fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected by our activities.
4. Implement risk management strategies based on valid data and sound science.
5. Seek continual improvement of our health and safety performance.
6. Seek continual improvement of our environmental performance.
7. Contribute to conservation of biodiversity and integrated approaches to land use planning.
8. Facilitate and encourage responsible product design, use, re-use, recycling and disposal of our products.
9. Contribute to the social, economic and institutional development of the communities in which we operate.
10. Implement effective and transparent engagement, communication and independently verified reporting arrangements with our stakeholders.

Regionally, a Southern African report was also produced collaboratively during the two year tenure of the MMSD project, namely: *Minerals, Mining and Sustainable Development in Southern Africa* (Hoadley et al, 2002). With respect to closure, it focuses largely on the social aspect thereof which is beyond the remit of this study. It does however echo the global MMSD report in stating that “the goal of sustainable development with regard to the natural system is to ensure equitable and sustainable use of the environment and natural resources for the benefit of present and future generations” (Hoadley et al, 2002: 61). The report goes on to provide the following broad guidelines/principles which the mining and minerals sector will have to work towards to contribute positively to sustainable development (Hoadley et al, 2002: 61):

1. Minimize the impacts of their activities on land, water, air and biological communities, [an emphasis is placed on water resources with Southern Africa being semi-arid.]
2. Operate within the carrying capacity of the ecosystems in which they are located,
3. Foster an understanding of the value of the area's natural heritage, and
4. Minimise the exhaustion of non-renewable resources by, for example, sponsoring and promoting research and development in product recycling, waste minimisation and the search for alternative raw materials.

In summation of the MMSD project’s role in South Africa, in Luke Danielson’s 2006 report *Architecture for Change: An Account of the MMSD Project*, a post script is included: *Comments From Some Colleagues*. Notably Dr. Daniel Limpitlaw’s contribution sheds light on the MMSD’s impact on South African mining and its sustainable development policies, and
is quoted here in full (Danielson, 2006: 90): “The MMSD project occurred at a critical time in the development of SD [sustainable development] awareness in southern Africa. The project contributed significantly to raising awareness of the challenges facing the mining and minerals industry and created bridges between stakeholders for dialogue. The momentum generated by MMSD was augmented and carried forward by the South African Government through new minerals legislation [the Minerals and Petroleum Resources Development Act of 2002] that explicitly requires sustainability to be considered; by industry via a number of projects coordinated by the Chamber of Mines (on key issues such as small scale mining, resettlement and rehabilitation) and by academia through the formation of centres dedicated to building capacity for promotion of SD, such as the Centre for Sustainability in Mining and Industry at the University of the Witwatersrand.”.

Thus it can be seen that South Africa’s uptake and involvement in sustainable development and mining policy formulation is well established and recognised at a global level. Notably the key South African mineral legislation, the 2002 Mineral and Petroleum Resources Development Act (DME, 2002), was developed in light of the learnings of the then recent MMSD project.

A follow up report: MMSD +10: Reflecting on a Decade was produced in 2012 (MMSD, 2012). It acknowledges that the initial report was seminal in the mining and sustainable development debate; that in the past ten years there has been a valuable increase in mining standards and guidelines aimed at sustainable development; and yet despite such policy and strategy level advancement, including individual cases of best practice, there remains a highly variable track record of successes in reality – which can often be attributed to the complexity of the real-world operations (i.e. the gap between policy and mine site). It goes on to note that often issues arise where, the practical implementation and reporting of such initiatives is poorly translated in actuality; as well as the ineffective policing and meeting out of punitive measures for non-compliance. Other ongoing hurdles to achieving sustainable development through mining include: the lack of government capacity and the will to foster it, artisanal and small scale mining which is often conducted illegally (and may undo closure efforts), effective community development, and approaching mining and sustainable development in a truly integrated manner. Furthermore it acknowledges ‘new’ sustainable development challenges that the sector faces, viz.: climate change, competition from emerging economies, and the re-emergence of the ‘resource nationalisation’ debate (Buxton, 2012).
2.3.3.3 The JPOI

The MMSD project discussed above was produced in time for presentation at the Johannesburg World Summit on Sustainable Development (WSSD 2002, also known as Rio +10). The major output of the 2002 WSSD was the *Johannesburg Plan of Implementation* (JPOI). The JPOI built on Agenda 21 and the fundamental principles produced at the 1992 WSSD in Rio de Janeiro. It detailed an implementable action plan for sustainable development across the social, environmental, economic and governance facets of sustainable development. Section 46 addressed mining specifically (WSSD & UN, 2002):

**46.** Mining, minerals and metals are important to the economic and social development of many countries. Minerals are essential for modern living. Enhancing the contribution of mining, minerals and metals to sustainable development includes actions at all levels to:

(a) Support efforts to address the environmental, economic, health and social impacts and benefits of mining, minerals and metals throughout their life cycle, including workers’ health and safety, and use a range of partnerships, furthering existing activities at the national and international levels among interested Governments, intergovernmental organizations, mining companies and workers and other stakeholders to promote transparency and accountability for sustainable mining and minerals development;

(b) Enhance the participation of stakeholders, including local and indigenous communities and women, to play an active role in minerals, metals and mining development throughout the life cycles of mining operations, including after closure for rehabilitation purposes, in accordance with national regulations and taking into account significant transboundary impacts;

(c) Foster sustainable mining practices through the provision of financial, technical and capacity-building support to developing countries and countries with economies in transition for the mining and processing of minerals, including small-scale mining, and, where possible and appropriate, improve value-added processing, upgrade scientific and technological information and reclaim and rehabilitate degraded sites.

As can be seen, consideration of the entire mine life cycle and stakeholder inclusion are specifically highlighted as challenges which need to be thoroughly and iteratively planned such that mine closure may contribute positively to sustainable development.
2.3.3.4 Berlin II – Guidelines for Mining and Sustainable Development

The 2002 *Berlin II: Guidelines for Mining and Sustainable Development* built on the 1991 *Berlin Round Table on Mining and the Environment*, and was hosted by the United Nations and the German Foundation for International Development. The product of Berlin I was the first edition of *Environmental Guidelines for Mining Operations* in 1994. Due to legislative, policy and fiscal changes in the intervening decade, the need for an updated *Berlin II Guideline* was identified and acted upon (UN, 2002b). This occurred within the context of the advent/increase of environmental conditions attached to credit and insurance provision; the development, uptake and standardisation of environmental management systems and voluntary industry codes; increased public awareness and pressure regarding sustainable development; all of which lead to significant changes in regulatory milieus. It was with this backdrop that the *Berlin II Guidelines* sought to address five sustainability themes for each stage of the mine life cycle (UN, 2002b: 2):

- Mining and sustainable development;
- Regulatory frameworks;
- Environmental management;
- Voluntary undertakings; and
- Community consultation and development.

Thus the *Berlin II Guidelines* consist of examples of legal and management frameworks from various countries with an established mining industry. As such they are not prescriptive, but rather are a guide for policy makers to tailor to local conditions, such that mining serves sustainable development goals. However the guidelines do put forward a set of fifteen minimum principles to which the mining industry should abide to foster sustainable development, as follows (UN, 2002b: 4):

Governments, mining companies and the minerals industries should as a minimum:
1. Recognize environmental management as a high priority.
2. Recognize the importance of socio-economic impact assessments.
3. Establish environmental accountability.
4. Encourage employees at all levels to recognize their responsibility for environmental management.
5. Ensure the participation of and dialogue with the affected community and other directly interested parties.
6. Adopt best practices to minimize environmental degradation.
7. Adopt environmentally sound technologies.
8. Seek to provide additional funds and innovative financial arrangements to improve environmental performance of existing mining operations.
10. Reinforce the infrastructure, information systems service, training and skills in environmental management in relation to mining activities.
11. Avoid the use of such environmental regulations that act as unnecessary barriers to trade and investment.
12. Recognize the linkages between ecology, socio-cultural conditions and human health and safety, the local community and the natural environment.
13. Evaluate and adopt, wherever appropriate, economic and administrative instruments to encourage the reduction of pollutant emissions and the introduction of innovative technology.
14. Explore the feasibility of reciprocal agreements to reduce transboundary pollution.
15. Encourage long term mining investment by having clear environmental standards with stable and predictable environmental criteria and procedures.

The Berlin II Guidelines highlight that sustainable development should be viewed as a process, and that mining plays a part in the realisation thereof. It goes on to point out that with current technology and management practices there is no reason for mining to impart unmitigated impacts on the environment. It thus puts forward a guideline of best practices and models which can and have been implemented (through each of the themes listed above) to foster sustainable development through mining.

2.3.3.5 The EIR

Halfway through the MMSD project, The World Bank committed to producing a report on the mining industry including oil and gas. The project was entitled the Extractive Industries Review (EIR) and aimed at ascertaining if the World Bank’s aim of poverty reduction through investment (in this case, investment in mining) was being meaningfully and effectively met considering the sustainable development challenges mining was facing. According to Worral et al (2009: 1428), the World Bank defined sustainable development in mining: “as having financial viability, environmental soundness, social responsibility, effective governance and long term community value”. The final 2003 report, entitled Striking A Better Balance concluded that although sustainable development could be met through continued investment in mining, that certain conditions have to be in place for this to be true, namely (Salim, 2003: vii):

1. Pro-poor public and corporate governance, including proactive planning and management to maximize poverty alleviation through sustainable development;
2. Much more effective social and environmental policies; and
Specific sections of the report do make mention of planning for mine closure and adequately managing the environmental, economic and social aspects and impacts thereof. Since this initial report, an annual Extractive Industries Review is produced by the World Bank Group. It provides a summary of the group’s activities in the sector within the context of sustainable development. However, more recent reports from the World Bank (WBG, 2010; WBG 2012) focus on economic development and poverty reduction achieved through mining investments, for example: “[The] WBG’s objective in the extractive sector is to ensure that natural resources contribute positively to economic development” (WBG 2012: v).

2.3.3.6 The GRI and The Mining and Metals Sector Supplement

The Global Reporting Initiative (GRI) was initially established in 1997 and the first version of the GRI guidelines was produced in 2000. It is a voluntary sustainable development reporting initiative which has garnered significant uptake by organisations across all sectors and is now in its fourth revision (Brown et al, 2007). Reporting is structured around three main facets of an organisation’s operations, namely: Social, Environmental and Financial. This has come to be known as ‘Triple Bottom Line’ reporting. The guidelines are such that they seek to be implementable across organisations of any type, size and location (GRI, 2011).

There are also sector specific supplements to the GRI Guidelines. The most recent and relevant supplement is the Mining and Metals Sector Disclosures version 4.0 published in May 2013 (GRI, 2013). This sector guideline corresponds with G4.0 version of the Sustainability Reporting Guidelines. This mining supplement provides “a summary of the mining and metals sector-specific disclosures, performance indicators, and commentary on the G4 Guideline” in the form of a merged document. Mine closure is specifically referred to under the following sections:

- EN12: The identification of significant impacts on biodiversity due to mine closure (and resettlement).
- Society: Disclosure on management approach - Report the scope of closure planning; its associated financial provision, and its coverage of health, safety, social, environmental, legal, governance and human resource aspects.
- MM10: Closure planning - Number and percentage of operations with closure plans.

The GRI guidelines have globally become a de facto standard for publicly reporting companies’ triple bottom line performance (MacLean & Rebernak, 2007). For 2012 almost 150 mining companies produced public sustainability reports against the GRI’s guidelines (GRI, 2014). Thus it can be seen that mining companies seeking to publically report as per the GRI guidelines, have to include high level reporting on mine closures.
### 2.3.3.7 Framework for Responsible Mining

In 2003, Tiffany & Co., EARTHWORKS, and World Wildlife Fund (WWF, now known as World Wide Fund for Nature), hosted a “responsible-source minerals dialogue”. The discussions focussed on the environmental and social impacts of mining and mined products and involved stakeholders ranging from NGO’s and technical experts to investors and retailers. The upshot of this dialogue was the identification of the need for a document identifying best practices in the sector whereby sourcing and investing policies could be informed. The resultant *Framework for Responsible Mining: A Guide to Evolving Standards* was produced in 2005 by the Centre for Science in Public Participation (CSP2), the World Resources Institute (WRI) and the WWF (Miranda et al, 2005). The report explicitly drew on forerunning initiatives such as the Mining, Minerals, and Sustainable Development (MMSD); Extractive Industries Review (EIR); Global Reporting Initiative (GRI) including the mining sector supplement; and the International Union for Conservation of Nature (IUCN)–International Council on Mining and Metals (ICMM) dialogue. The framework espouses seven common principles which stem from international agreements, such as Agenda 21 and the Rio Declaration. These principles have been incorporated into policy and legislation throughout the world. The principles are (Miranda et al, 2005: 6 - 7):

1. Sustainable development,
2. Equity,
3. Participatory decision making,
4. Accountability and transparency,
5. Precaution,
6. Efficiency,
7. Polluter responsibility [The ‘polluter pays’ principle].

The study goes on to delineate ‘Norms’ and ‘Leading Edge’ practices in the mining industry i.e. common practice vs. best practice. The report does specify that hard rock mining (base and precious metals and gemstones) is its primary focus, and not fossil fuel industries (e.g. coal). Specifics areas of recommendation regarding environmental aspects of mining which are relevant to this study are: environmental impact analysis, water contamination and use, acid mine drainage, air quality, energy consumption, noise, waste management, reclamation and rehabilitation, post-closure, good governance and reporting (Miranda et al, 2005). The specifics of these recommendations are too detailed for inclusion in this literature review, suffice it to say, that these aspects need to be considered and practically implemented in abiding by sustainable development in mining principles.
2.3.3.8 Enduring Value: The Australian Minerals Industry Framework for Sustainable Development


*Enduring Value* is founded on the *Australian Minerals Industry Code for Environmental Management* (MCA, 2005b) and seeks to give practical effect at site level to the ICMM’s 10 sustainability principles. At the time of publication of these guidelines they were aligned with the 2002 GRI *Sustainability Reporting Guidelines and Mining and Metals Sector Supplement*. Accordingly, mining operations are effectually steered toward meeting community expectations, with the intent of contributing long term benefits to society through the expounding of leading practices.

At the core of *Enduring Value’s* framework is the commitment to the concept of acquiring and maintaining a ‘social licence to operate’. This is defined as being complementary to a legislative operating licence, and is an unwritten social contract between mining project and the interested and affected communities. Such a social operating licence must be earned and maintained by the mining venture/operation by means of consistent inclusion, transparency, responsibility and good performance. Without such buy-in, a public, counter to the development, may halt a project altogether. Commitment to *Enduring Value* is a requirement of membership to the Australian Minerals Council; however non-members may also subscribe to it voluntarily. The primary obligations stemming from this commitment are (MCA, 2005a: 6):

- The progressive implementation of the ICMM Principles and Elements;
- Public reporting of site level performance, on a minimum annual basis, with reporting metrics self-selected from the Global Reporting Initiative (GRI), the GRI *Mining and Metals Sector Supplement* or self-developed metrics; and
- The assessment of the systems used to manage key operational risks.

In its goal of fostering sustainable development through mining, the *Enduring Value* framework goes on to espouse the practically implementable strategies for the ten Sustainability principles of the ICMM. However, as with the *Framework for Responsible Mining* report (Section 2.3.3.7) these implementation measures are too detailed for inclusion in this literature review. Nevertheless, from these detailed recommendations it can be seen that *Enduring Value* is a comprehensive and onerous framework which seeks to foster sustainable development through responsible mining.
2.3.3.9 BellagioSTAMP: Sustainability Assessment and Measurement Principles

BellagioSTAMP is a set of high level principles aimed at guiding measurements of sustainability improvements. It was designed in cooperation between a team of experts from the International Institute for Sustainable Development (IISD) and Organisation for Economic Co-operation and Development (OECD) (Pintér, 2009). This set of sustainable development measurement principles was officially launched in 2009 at the 3rd OECD World Conference (IISD, 2013). These principles are not simply principles of sustainability, but are principles of sustainability assessment and can be used to “to help guide overall indicator system design and analysis that—over time—will result in convergence and better accountability.” (Pintér et al, 2012: 21). These proposed principles upon which sustainability assessments should be based are as follows (IISD, 2013):

1. Guiding Vision
2. Essential Considerations
3. Adequate Scope
4. Framework and Indicators
5. Transparency
6. Effective Communication
7. Broad Participation
8. Continuity and Capacity

These broad principles, and the guidance notes provided on each, seek to provide a rigorous context within which any sustainability assessment and reporting can best be conducted.

2.3.3.10 Balancing Mining and Sustainable Development – APEC Report

In 2010 the Asia-Pacific Economic Cooperation (APEC) identified that mining and sustainable development is a major issue to be addressed in the region. Due to the substantial mining production of this predominantly developing region, an investigation into balancing mining’s economic benefits with environmental preservation and social upliftment was deemed necessary. The resulting report was entitled: Balancing Mining and Sustainable Development (MTF, 2010).

A key argument put forward is that mining of non-renewable resources may be deemed acceptable, if there is net benefit provided across economic, social and environmental spheres while negative consequences are either ameliorated or avoided. However serious consideration needs to be invested in attaining this balance. The principle and systematic methodology proposed to achieve sustainable development in mining is based on Azapagic (2004: 640) and is put forward as follows (MTF, 2010: 4):
1. Identification of stakeholders and key sustainability issues;
2. Programs and actions needed to address these issues;
3. Development of sustainability indicators to enable performance measuring and monitoring;
4. Progress evaluation to ensure continuous improvement of the triple bottom line (economy, social and environment); and
5. Information sharing and communication with stakeholders.

The report thus investigates a wide range of mineral commodities in the Asia-Pacific region, passes comment on the status of sustainable development in each case, and ultimately provides suggestions for fostering sustainable development in the region’s mining sector.

2.3.3.11 International Finance Corporation (IFC) Sustainability Framework and Performance Standards and IFC & World Bank Environmental, Health and Safety Guidelines for Mining

As a requirement for garnering funding from the International Finance Corporation (IFC) (of the World Bank Group), the IFC has mandated a *Sustainability Framework* to which clients must abide. Though not specific to mining, many mining ventures seek funding from the IFC. The IFC’s *Sustainability Framework* is thus a method of managing investor risk and committing to funding sustainable development (IFC, 2012). The *Sustainability Framework* comprises: the IFC’s *Policy and Performance Standards on Environmental and Social Sustainability*, and IFC’s *Access to Information Policy*. The most recent version of these *Environmental Performance Standards* is effective as of 1 January 2012. These standards provide guidance based on a life-cycle approach in identifying and managing environmental and social risks, such that business is conducted in a sustainable manner and that development opportunities are maximised. There are eight broad ‘Performance Standards’ thus prescribed (IFC, 2012: 2):

1. Assessment and Management of Environmental and Social Risks and Impacts
2. Labour and Working Conditions
3. Resource Efficiency and Pollution Prevention
4. Community Health, Safety, and Security
5. Land Acquisition and Involuntary Resettlement
6. Biodiversity Conservation and Sustainable Management of Living Natural Resources
7. Indigenous Peoples
8. Cultural Heritage
A mining specific guideline to which IFC and World Bank clients must adhere has also been developed, viz: *Environmental, Health and Safety Guidelines for Mining* (IFC, 2007a). This guideline lays out mining industry specific ‘Impacts and Management’ as well as ‘Performance Indicators and Monitoring’. Projects are expected to meet all local legislative requirements as well as the guideline’s requirements; and where these differ, projects are expected to fulfil whichever is more stringent. The report goes on to classify mining’s environmental impacts into the following categories (IFC, 2007a: 2):

- Water use and quality
- Wastes (including rock dumps and tailings)
- Hazardous materials
- Land use and biodiversity
- Air quality
- Noise and vibrations
- Energy Use
- Visual Impacts

The guidelines describe the above categories of environmental impacts, and go on to prescribe minimum management measures, practices and strategies. For example, stipulating the development of a detailed water balance; the implementing of a water reuse strategy; stormwater, flooding and erosion control; AMD potential characterisation and management into closure and post-closure if necessary; adequate structural and geochemical design of dumps and tailings; creating buffer zones and fauna corridors for sensitive areas, amongst others (IFC, 2007a). The guideline’s section, ‘Performance Monitoring and Indicators’, along with the IFC’s *Environmental, Health, and Safety General Guidelines* (IFC, 2007b), go on to provide measurable limit values for vectors of environmental impact. The guideline values are based on good international industrial practice and, in conjunction with the implementation of the aforementioned management guidelines, are expected to be achievable under normal operating circumstances. The guideline values and measures prescribed span across: effluent emissions both to air and water, including ambient qualities; water and energy conservation; noise and waste targets; and finally, hazardous materials and contaminated land management.

### 2.3.3.12 Equator Principles

“The Equator Principles (EPs) is a risk management framework, [voluntarily] adopted by financial institutions, for determining, assessing and managing environmental and social risk in projects and is primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making.” (Equator Principles, 2011).
It is thus that member financial institutions, which provide project funding to clients (e.g., mining ventures), have to themselves, and consequently the projects they fund, abide by the *Equator Principles Framework*. In this manner funding conditions are used to influence clients to foster sustainable development. As with the IFC and World Bank initiatives described above, the EP’s are not limited to the mining sector, but many mining companies seek to abide by them, hence their inclusion here. This framework has in fact been aligned with the IFC *Performance Standards* which must also be adhered to. The ten Equator Principles are briefly laid out as follows (Equator Principles, 2013: 5 - 10):

1. **Review and Categorisation** – A categorisation of environmental and social risk into three classes (A – High; B – Medium; C – Low).
2. **Environmental and Social Assessment** – All category A and B projects must conduct a social and environmental assessment which includes adequate management and mitigation measures.
3. **Applicable Environmental and Social Standards** – local social and environmental legislation must be complied with.
4. **Environmental and Social Management System and Equator Principles Action Plan** – All category A and B projects required to implement an EMS (Environmental Management System).
5. **Stakeholder Engagement** – All category A and B projects require tailored stakeholder engagement to be conducted through consultation and participation.
6. **Grievance Mechanism** – All category A and B projects require a grievance mechanism to be in place for interested and affected parties to raise and have resolved social and environmental concerns.
7. **Independent Review** – All category A and B projects require third party review of compliance to the Equator Principles.
8. **Covenants** – For all projects, the client will covenant in the financing documentation to comply with all relevant host country environmental and social laws, regulations and permits.
9. **Independent Monitoring and Reporting** – Assess project compliance with the Equator Principles and ensure ongoing monitoring and reporting over the life of the loan and after Financial Close.
10. **Reporting and Transparency** – Client and financial institution reporting requirements.

It is thus that the Equator Principles seek to foster sustainable development through leveraging investment terms and conditions, and thereby meet investor expectations of sustainably sound investment.
The Towards Sustainable Mining (TSM) initiative by The Mining Association of Canada (MAC) was preceded by Whitehorse Mining Initiative of the early 1990’s. The Whitehorse Initiative consulted the public at large and sought to align communities’ and mining projects’ visions. However, despite the valuable policy documents produced, the Whitehorse Initiative provided no implementation mechanisms. Contemporaneously, there were a number of high profile tailings dam failures in Canada which ultimately lead to public pressure halting certain mining ventures. The MAC thus saw the need for an industry-based voluntary initiative to improve mining’s track-record and reputation. After numerous years of research and consultation, in 2004 the TSM initiative was launched. Participation in TSM is a condition of membership to MAC (MAC, 2013).

The TSM’s vision statement speaks to providing society’s needs for minerals, metals and energy products while maintaining a social licence to operate “through a demonstrated commitment to sustainable development”. This includes the industry’s actions demonstrating a responsible approach to social, economic and environmental performance “that is aligned with the evolving priorities of our communities of interest”. This is underlain by the guiding values of honesty, transparency and integrity (MAC, 2013: 5). The TSM thus espouses certain ‘Guiding Principles’ whereby “TSM members will demonstrate leadership worldwide” which exhibits sustainable development through mining.

Members of the TSM initiative are specifically externally audited at the facility level on their performance and reporting against the initiative’s standards. There are six performance elements, each with their own protocol documents including associated indicators, against which members must perform, namely (MAC, 2012):

- Tailings Management
- Energy Use and Greenhouse Gas (GHG) Emissions Management
- Aboriginal and Community Outreach
- Crisis Management Planning
- Biodiversity Conservation Management
- Safety and Health
- Mine Closure [currently under development]

Thus the TSM initiative is an evolving set of sustainability principles and performance elements which seek to visibly demonstrate to interested and affected parties the commitment and track-record of members to fostering sustainable development through mining projects.
2.3.3.14 A Mining Policy Framework

At the 2002 WSSD, a number of countries decided to commit to enabling the mining sector’s role in sustainable development; the outcome being paragraph 46 of the JPOI. Thus, in 2005, a partnership was formed between interested countries and the IGF (InterGovernmental Forum on Mining, Minerals, Metals and Sustainable Development). Membership is voluntary and is recognised by the United Nations. Through sharing best practice and expertise the forum aims to: “Improve, enhance, and promote the contribution of the mining, minerals and metals sector to sustainable development and poverty reduction” (IGF, 2013: 3).

Through its research work, the IGF produced a Mining Policy Framework which was tabled in New York at the nineteenth session of the United Nations Commission on Sustainable Development (CSD19), May 2011. The framework is a compilation of best governance practices in relation to mining and sustainable development. The IGF’s Mining Policy Framework seeks to be a comprehensive model which, if progressively implemented, will facilitate mining in maximising its contribution to sustainable development.

The IGF distinguishes good governance (both public and private) as being the key to the mining sector contributing to sustainability. This sustainability must however seek to go beyond the mining activity itself as the finite nature of a mine site is a given. That is to say: “Sustainability is the outcome of transforming the assets generated in the course of mining into other forms of assets that persist beyond the mine closure and are tools for development beyond the mining sector” (IGF, 2013: 4). Key aspects of note are that all revenue streams from mining must be managed toward this end, and that the capacity for good governance must be in place; else mining shall not contribute toward sustainable development and poverty reduction. It particularly acknowledges that mining’s post-closure legacy is what must contribute to sustainable development. Without a net positive legacy, which extends beyond the mining sector, mining cannot be considered sustainable. To these ends the IGF’s Mining Policy Framework provides governance guidance on the following aspects of mining (IGF, 2013):

- Legal and policy environment
- Financial benefit maximization
- Socio-economic benefit maximization
- Environmental management
- Post-mining transition
- Artisanal and small-scale mining (ASM)

Thus, it is through governance guidance that the IGF on Mining, Minerals, Metals and Sustainable Development seeks to improve the mining sector’s contribution to sustainable development.
In 2010 the World Economic Forum (WEF), established a multi-stakeholder process and produced the first report of the Responsible Mineral Development Initiative (RMDI); it identified the key challenges hindering responsible mineral development. In 2011, a framework of six ‘building blocks’ was created to address the key challenges previously identified. These six “building blocks” seek to “foster responsible, sustainable mineral development, thus enabling better integration of mining wealth into national economies” (RDMI, 2011: 2):

1. Progressive capacity building and knowledge sharing among all stakeholders.
2. A shared understanding of the benefits, costs, risks and responsibilities related to mineral development.
3. Collaborative processes for stakeholder engagement throughout the life cycle of mining projects.
4. Transparent processes and arrangements.
5. Thorough compliance, monitoring and enforcement of commitments.
6. Early and comprehensive dispute management.

This 2011 report goes on to highlight and propose specific actions (supported by case studies) for each “building block”. It also notes that such responses need to be enacted cooperatively and in parallel. In 2012 the RDMI developed the Mineral Value Management (MVM) tool which seeks to foster diverse stakeholder understanding of the holistic drivers of value from mining. In 2013 the RDMI released its third report (RDMI, 2013) which focuses on the definition and application of said MVM tool.

**2.3.3.16 Conclusion**

The review of these benchmark, multi-stakeholder initiatives and reports has interrogated and sought to elucidate mining’s role and relationship with sustainable development as its goal. The principles, both stated and inherent, at the confluence of mining, mine closure and sustainable development are what most concern this study. As per Robertson (1999), the fourth tenant of Sustainability for Mining is: “Planning and provision for post mining sustainable land use management and custodial succession are necessary.” Thus, “While the concept of sustainable development is now widely accepted […], achieving it implies the definition of goals and ways to measure progress towards the goals.” (MTF, 2010: 36). This, in alignment with the foregoing principles, highlights the need to find a measure for the environmental sustainability of mine closure which is the aim of this research.
2.3.4 The Impact of Sustainable Development Policy on South Africa and its Mining Sector

It was in the aforementioned global context, that in 1996, sustainable development was enshrined in Section 24 of the new South African Constitution, Act no. 108 of 1996 (RSA, 1996). See Section 1.1 for this section quoted in full. Following on from this in 2002, with reference to mining in particular, South Africa promulgated The Mineral and Petroleum Resources Development Act (Act 28 of 2002) (MPRDA) (RSA, 2002). The act gives effect to sustainable development in the preamble: “Affirming the State’s obligation to protect the environment for the benefit of present and future generations, to ensure ecologically sustainable development of mineral and petroleum resources and to promote economic and social development;” And in Chapter 2: Fundamental Principles, Section 2, Objects of the Act: “(h) give effect to section 24 of the Constitution by ensuring that the nation's mineral and petroleum resources are developed in an orderly and ecologically sustainable manner while promoting justifiable social and economic development.”

Sustainable development was further advanced at the World Summit on Sustainable Development in Johannesburg in 2002, which resulted in the Johannesburg Plan of Implementation (JPOI) (WSSD & UN, 2002). This document aimed at implementable actions to foster sustainable development. Paragraph 162 (b) of the JPOI requires that: “States should take immediate steps to make progress in the formulation and elaboration of national strategies for sustainable development and begin their implementation by 2005.” As a first step, South Africa in 2003, responded to the JPOI by drafting the locally tailored JPOI Response Strategy (DEAT, 2003). In this document one of the strategic priorities of the then DME (South African Department of Minerals and Energy) is clearly stated as: “[to ensure] Sustainable development and growth through minerals and energy resources for the benefit of all South Africans” (DEAT, 2003: 30).

This JPOI Response Strategy was an initial outline on how to complete South Africa’s National Framework on Sustainable Development (NFSD). The National Department of Environmental Affairs and Tourism (DEAT) was then tasked to draft this NFSD. The framework touted the vision: “South Africa aspires to be a sustainable, economically prosperous and self-reliant nation that safeguards its democracy by meeting the fundamental human needs of its people, by managing its limited ecological resources responsibly for current and future generations, and by advancing efficient and effective integrated planning and governance through national, regional and global collaboration” (DEAT, 2008: 8).

The NFSD was adopted by the Cabinet in June, 2008. The NFSD particularly advocated a systems approach to sustainable development. The NFSD puts forward certain sustainable development principles, namely (DEAT, 2008: 8 - 9):
‘First order’ or fundamental principles relate to those fundamental human rights that are guaranteed in the Constitution:

- Human dignity and social equity
- Justice and fairness
- Democratic governance

‘Substantive principles’ are already enshrined in policy and legislation, and speak to the conditions which should be met in order to have a sustainable society. A systems and continuous improvement approach underlie these principles:

- Efficient and sustainable use of natural resources
- Socio-economic systems are embedded within, and dependent upon, ecosystems
- Basic human needs must be met to ensure resources necessary for long term survival are not destroyed for short term gain

‘Process principles’ establish a few clear principles that apply specifically to the carrying out of the NFSD:

- Integration and innovation
- Consultation and participation
- Implementation in a phased manner

Concurrently to the NFSD, along with the JPOI Response Strategy as a driver, the DME initiated the Sustainable Development through Mining (SDM) initiative. The SDM aimed to define and elaborate the mining sector’s position and strategic responses, including sustainable development projects, in the context of the NSFD process. The goal of this SDM initiative was that: “by 2010 the South African Mining Industry contributes optimally to sustainable development” (DME, 2007).

In 2007 the initiative produced a detailed discussion document entitled: *A strategic framework for implementing sustainable development in the South African minerals sector: towards developing sustainable development policy and meeting reporting commitments, [and includes:] Sustainable development through mining initiative: development of indicators for monitoring the contribution of the South African mining and minerals sector to sustainable development* (DME, 2007). The report specifies the following objectives would support the achieving of the SMD vision:

- To identify and prioritise ownerless and derelict mines for rehabilitation.
- Develop a common vision for sustainable development through mining amongst stakeholders.
- Develop a framework and strategy for sustainable development for South Africa.
- Develop and implement measures to strengthen environmental enforcement.
- Support for socio-economic and human resources development initiatives.
The second key goal of the SDM program is also notably relevant to this study:

- Enabling South Africa to measure and assess progress towards sustainable development objectives in the minerals sector.

The report also highlights the fact that there has generally been a lack in sustainable development strategy, policy and guidance in respect of sustainable mine closure in South Africa. However, despite the SDM being set up as an on-going initiative, after a second 2009 draft of this discussion report (DME, 2009), which pushes out to 2015 achieving the aforementioned vision, no further reports have been produced.

Returning to South African national policy and expanding on the 2008 NFSD framework document and integrating other sustainable development learnings, the National Strategy for Sustainable Development and Action Plan, also known as NSSD 1 (2011–2014), was drafted in 2011 (DEA, 2011). Its aim is to support the NFSD by providing the strategic roadmap and action plans to successfully implement the NFSD. The NSSD 1 was approved by Cabinet on 23 November 2011 and is to be implemented between 2011 and 2014. Its progress is to culminate in the NSSD 2 being drafted for 2015-2020. The NSSD 1 (2011) identified five strategic priorities (DEA, 2011: 5):

1. Enhancing systems for integrated planning and implementation
2. Sustaining our ecosystems and using natural resources efficiently
3. Towards a green economy
4. Building sustainable communities
5. Responding effectively to climate change

These strategic priorities devolve into numerous specific objectives and from thence identify 113 interventions and associated headline indicators intended to monitor implementation. The NSSD1 specifically refers to sustainable development and mining in its strategic priority #3. It starts by stating: “Cognizance must be given to the fact that since mineral resources are finite, the mining industry is inherently unsustainable” (DEA, 2011: 23).

It then goes on to state that mining can contribute towards sustainable development provided that methods of production seek to minimise environmental impact, but more importantly that the development of alternative, sustainable, post-closure livelihoods is provided for. Increases in extraction, manufacturing, reuse and recycling efficiencies are also espoused, along with enhancing downstream beneficiation (DEA, 2011). Mining related targets and indicators stemming from this priority #3 are:

- 15% reduction by 2015 of energy use in industry and mining.
- Reduction of water use by ? [not quantified]
- Reduction of industrial and mining waste.
According to Ms. L. Hart-Richards (2013) it is envisaged that the Department of Environmental Affairs will commence work on the NSSD2 during 2014.

A more recent policy document, *The South African National Development Plan: Vision 2030*, in its references to mining and targeted development actions, does not speak to environmental sustainability but rather only to the socio-economic sustainability of the sector (NPC, 2011). Furthermore, on the 14 June 2013 a *Draft Framework Agreement for a Sustainable Mining Industry* was signed by organised labour, business and the South African government. Despite the title utilising the term ‘sustainable’, the ten page document does not once mention environmental concerns; rather it speaks to “sustainable growth and transformation of the mining industry”. It focuses entirely on social, economic and governance issues aiming to: “reposition the mining industry to become attractive to investors and a more meaningful contributor to job creation”. Implicit environmental considerations at best comprise the commitment to: “Improve the effectiveness of mechanisms for legal and regulatory compliance” (The Presidency, 2013; Ettershank, 2013).

As can be seen from these two most recent policy documents regarding the ‘sustainability’ of mining in South Africa, there is a heavy focus on harmonising social and economic aspects with little discussion of environmental prerogatives. This may be due to the governance and labour issues with which the sector is embattled post the 2012 Markiana tragedy (Leon, 2013). That overall sustainability performance as an indicator is found to be relegated, is moreover confirmed by a quantitative study of South African mining houses’ public reports by Sorensen (2012). These recent tendencies to forgo the environmental aspect of sustainable development in mining in South African policy documents is concerning, but the ‘on-the-ground’ status quo shall be further investigated in Chapter 4.

### 2.3.5 Conclusion: Sustainable Development Principles and Modes

The purpose of the review of these global and South African sustainable development initiatives has been to distil a consolidated list of sustainable development principles and modes. That is to say, to lift the prime principles of sustainable development in mining from this literature. On the whole this list focuses on the environmental aspect of sustainable development. It is also generated within the context of ‘sustainable development in mining’ literature and often from the perspective of what the mining industry should do. Nevertheless, due to the interrelated nature of things and sustainable development in particular, certain social and economic principles are included. Thus the following list (Table 3) of ‘sustainable development principles in mining’ has been compiled from an aggregation and distillation of the foregoing literature in Sections 2.3.3 and 2.3.4.
Table 3: Consolidated list of principles derived from major international ‘sustainable development in mining’ initiatives and corresponding South African policy.

<table>
<thead>
<tr>
<th>Key Sustainable Development Principle</th>
<th>Description and associated features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Precautionary principle</td>
<td>Exercising precaution where any uncertainties exist. This embodies responsible and proactive environmental stewardship of natural capital and consideration of: environmental carrying capacity, intergenerational concerns, cumulative and unquantified impacts despite immediate social and economic development demands.</td>
</tr>
<tr>
<td>2. Ethical corporate responsibility, community engagement and reporting</td>
<td>In which mining corporations are both supremely ethical in and accountable for their actions. This includes active, transparent, and effective communication and consultation; and seeking shared vision and integration, with interested and affected parties. Implementing sustainability reporting that is an effective and informative tool of communication and is also independently reviewed.</td>
</tr>
<tr>
<td>3. Subsidiarity principle and underpinning decision making</td>
<td>Decision making to occur at the appropriate level, which takes place as close as possible to, and with the input of, communities most directly impacted. Sustainable development principles and goals should underpin and drive decision making and governance i.e. the integration and primacy of sustainable development principles and goals throughout the mining process and concerned decision making structures.</td>
</tr>
<tr>
<td>4. Extensive Risk Management</td>
<td>Risk identification, mitigation and management must be extensive, exhaustive, iterative, and used as a decision making tool, with consideration and integration across social, environmental and economic spheres. Redundancies, disaster management and climate change should also be catered for.</td>
</tr>
<tr>
<td>5. Internalisation of costs</td>
<td>Costs, not always monetary and including social and environmental impacts (or externalities), must be accounted for and internalised in the execution of mining, thus reflecting a true cost of production. This should inform mining feasibility and steer operations towards sustainable development goals.</td>
</tr>
<tr>
<td>6. Iterative planning, monitoring and continual improvement</td>
<td>Long term planning with a view to continual improvement is essential; with such plans being updated, reintegrated and the mining trajectory adjusted as knowledge from environmental, social and cost monitoring is developed.</td>
</tr>
<tr>
<td>7. Investment in research, development and capacity building</td>
<td>Mining must be at the forefront of scientifically based research and development regarding persistent environmental and social impacts. This should be supported by investment in human capital at mines, in communities, government and academic institutions; such that the mining of natural capital is converted into human capital.</td>
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<tr>
<td>8. Rehabilitation, appropriate land use and local sustainability</td>
<td>With mining as a temporary land use, its legacy must be positive, appropriate and sustainable within the bio-physical locality and for its inhabitants. Rehabilitation must be undertaken as mining progresses and in line with the final sustainable land use. Persistent environmental and social impacts must be tackled with the goal of bringing about sustainable development outcomes at closed and legacy mining sites.</td>
</tr>
<tr>
<td>9. Systems approach and interconnectedness of principles</td>
<td>Mining must strive for efficiency (more with less); but it must also go beyond incrementally minimising negative impacts and become an effective implementing agent of sustainable development. Sustainable development as a paradigm is supported by systems or holistic thinking as opposed to reductionist, linear thinking. Social, environmental and economic concerns must be treated as a complex functioning whole where each affects the other. Implementing systems thinking in mine conception and design fosters effective, robust solutions which are responsive to change. Moreover cognition that all these principles are interlinked (talk to each other) is necessary, the recognition and application of which has a multiplying effect on sustainable development outcomes.</td>
</tr>
<tr>
<td>10. Waste as a resource: Greening a circular economy</td>
<td>Mining which aims for sustainable development seeks to diversify and ‘green’ the economy beyond mining with innovative responses to social, environmental and end-of-life circumstances. Going beyond reduction, reuse and recycling and seeking means to generate sustainable development where mining waste can effectively contribute to other useful processes and/or be positively returned to natural systems in a circular economy.</td>
</tr>
</tbody>
</table>

With the ultimate outcome of mining being closure, it can be argued that the goal at this end state must be the contribution of balanced sustainable development to the nation and locale. With these sustainable development principles and modes provided as a ‘how-to’ for the mining industry to direct operations toward sustainable development, the question remains as to how the mining industry may measure this trajectory. However, before this can properly be done, the process, goals and realities of mining and mine closure must be discussed.
2.4 MINING METHODS AND MINE CLOSURE

2.4.1 Mining Methods

Mineral deposits are to be found in a variety of geographic locations and geological formations. Consequently an assortment of mining methods have arisen. The four basic environs in which mining is conducted are underground, opencast, alluvial and marine environments. Here follows an explanation of the mining methods applied in these environs. This however is not an exhaustive discussion, rather the most common methods are briefly explained.

2.4.1.1 Historical Mining Methods

The very first historical mining methods involved ‘scavenging’ minerals which had outcropped at surface due to erosion (e.g. on a hillslope). As the resource was increasingly exploited, either an open pit was excavated or an adit developed, deeper into the hillface. See Figure 2. The other primitive mining method is that of panning alluvial deposits. A mineral deposit will have been eroded upstream by a river; through physical separation mechanisms present in the flowing river, such as density separation, the concentration of the mineral is enriched and a placer including nuggets may be formed, which are then separated by panning (Hammel et al, 2000). See Figure 3.

Figure 2: An adit mine.
(Source: Burchill et al, 2014)
2.4.1.2 Underground Mining Methods

Upon the advent of the industrial revolution, underground mining methods were advanced such that large quantities of (primarily) coal and iron ore could be extracted from beneath the surface in service of the mechanisation and industrialisation taking place. In the modern day, underground mining is usually practiced (for economic reasons to be detailed under the opencast Section 2.4.1.3) when the ore body is deeper than 60m below the surface. All underground mines have a shaft sunk either vertically or at an angle (inclined) to access the ore body. Typically underground water has to be pumped from the workings to afford access to the mineral resource. Regarding the basic principles of underground ore extraction there are four basic forms of underground mining, namely: board and pillar, caving, stoping and longwall mining (Hamrin, 1980). Given the unique characteristics of each ore body, there is a plurality of variations on these basic forms; however these variations are beyond the ambit of this introduction to mining methodologies and only the aforementioned basic forms shall be discussed.

2.4.1.2.1 Board and Pillar

Board and pillar (also known as room and pillar) mining was the first intensive underground mining method developed, and is now comparatively well mechanised (Figure 4). In this method the ore is extracted on a mostly horizontal plane (along the ‘seam’) while ‘pillars’ of unmined ore are left to support the roof strata. There are safety factors and extraction calculations involved in the sizes of the pillars left unmined; roughly 40% of the ore may
remain as pillars. Mining areas are divided into panels, which are separated by barrier pillars which are significantly larger, so as to prevent a chain-reaction collapse were one panel to cave in. Furthermore, additional roof support (such as rock bolting) may be used. The mining face is advanced either by cutting machinery, in the case of ‘soft’ minerals (e.g. coal); or blasting, in the case of hard ores (e.g. iron ore). The final stage of board and pillar mining may be ‘pillar extraction’ where mining retreats and extracts the pillars. This is similar to longwall mining, and may result in subsidence of surface ground level (Hamrin, 1980; de la Vergne, 2003; Smith, 2007).

![Figure 4: Underground board and pillar mining.](Source: Patriot Coal, 2012)

2.4.1.2.2 Longwall

The longwall mining method approaches 100% extraction of an underground mineral reserve. It is highly mechanised and is best suited to extensive horizontal seams which are of a consistent thickness. Parallel ‘haul ways’ are developed into the ore seam, a perpendicular ‘cut way’ is then mined to connect the termini of the ‘haul ways’, thus creating a ‘panel’. A cutting machine is then operated along this longwall face, and shears (extracts) the ‘panel’ in a backwards fashion, with conveyor belts transporting the ore away along the ‘haul ways’. See Figure 5. This leaves an unsupported ‘goaf’, which, as the cutting machine and its hydraulic roof support retreat, collapses causing surface subsidence. Through successive panels, the entire seam is mined in this fashion (EIA, 1995; MSEC, 2007; Smith, 2007).
2.4.1.2.3 Stoping

As defined by Hamrin (1980), a stope is an underground excavation made by removing ore from the surrounding rock. There are innumerable variations upon stoping as a mining method; it is most often used in inclined, vein, conical and irregular ore bodies as opposed to horizontal seams. On the whole, stoping is a method which suits competent rock conditions. That is, the roof and floor (also known as the hanging wall and foot wall respectively in an inclined ore body) need be of sufficient strength to remain unsupported for a period.

Essentially, an access shaft is developed, often adjacent the ore body and in an inclined spiral descending manner. At certain levels, horizontal mining tunnels are then developed into the ore body and the ore extracted. This extraction is usually by drilling and blasting of the ore, which is then mined by trackless machinery. The mined ore is thus transported to an underground loading point and transferred to the surface. The method is such that it can be suited to mine the ore body upwards (as in the case of shrinkage stoping) or downwards (as in vertical crater retreat). Waste rock is often used as a fill material after a section is mined out; the waste rock serves to increase the competency of the surrounding rock and thus support successive mining levels (Hamrin, 1980) (see Figure 6).
2.4.1.2.4 Caving

Caving relies on gravity to transport blasted, fractured ore from an upper level to a lower, loading level. This is achieved by undercutting the ore body in a predetermined configuration; the ‘hanging’ ore is fractured through drilling and blasting, which allows the broken ore to gravitate towards specifically designed draw points where the ore is then extracted by mechanised loaders. Such mining is generally used in low-grade, massive, friable yet competent ore bodies. Extraction rates are high, and dilution can be kept low if properly managed. If executed successfully, caving can be the lowest cost per ton underground mining method (Laubscher, 1994). However, this relies on certain technical factors of the design remaining operable throughout the life of the draw. Laubscher (1994) cites these aspects as being: cavability, fragmentation, draw patterns for different types of ore, drawpoint or drawzone spacing, layout design, undercutting sequence and support design. These features require a detailed knowledge of the area’s structural geology; as well as a good characterisation of the rockmass and its stress environment. Once committed to a caving layout however, there is little scope for change over the life of the draw operation (Munro, 2013).
2.4.1.2.5 Underground Mining Environmental Impacts

As detailed in Section 2.2.8, Table 2, the potential environmental impacts of mining are numerous. These range from land impacts (e.g. loss of land use, waste stockpile footprint) and air impacts (e.g. dust and fumes generation) to ecosystem impacts (e.g. habitat and biodiversity loss) and water impacts (e.g. AMD and aquifer/drainage modification). Underground mines potentially have less of an environmental impact than opencast mines due to the lack of overburden removal in accessing the resource. However surface subsidence certainly has attendant environmental impacts such as disturbing surface water drainage patterns. This includes altering geohydrological flows and water chemistries. The impacts associated with water can be compounded due to the interconnected nature of adjacent underground operations. Underground mines may also have other attendant surface impacts such as tailings dams and mine infrastructure which may obviate land use, pollute soils and/or cause dust emissions. (IFC, 2007a; Smith, 2009; GDACE, 2008).

2.4.1.3 Surface Mining Methods

As per Bullivant’s classification (1987) there are three basic forms of surface mining, namely, strip mining, terrace mining and open pit mining. Essentially the structure of the ore body will determine which method is used. Surface mining has intensified in scale with the introduction of colossal mechanised equipment such as draglines, hydraulic excavators and large tonnage trucks. Nevertheless, the economic viability of opencast mining is still primarily determined by the depth of the mineral deposit beneath the surface.

2.4.1.3.1 Strip Mining

Strip mining is applied to mineral seams such as coal which are relatively horizontal and large in extent i.e. high volume, low unit-cost product. An initial box cut is excavated where the overburden is removed (topsoil, subsoil) by truck and shovel. The exposed mineral may then be drilled and blasted and mined. Once this initial box cut is developed, a dragline or bucket wheel excavator may be moved into position to begin stripping the overburden in a series of long sequential lines. Mining operations follow the stripping operation and excavate the exposed mineral. When the stripping sequence returns in the opposite direction along the next advancement line, it may spoil (dump) the stripped material from the current cut into the void of the previous cut or alternatively it may be transported to a dedicated waste dump. The primary economic calculation which determines if strip mining is the mining method selected, is called the stripping ratio. This is a ratio of: the mass of overburden which needs to be removed to access a ton of the mineral. If the ratio is too high, strip mining is unfeasible. A
A rule of thumb is that if the mineral resource is in excess of 60m below surface, it is too deep to implement strip mining (Bullivant, 1987).

### 2.4.1.3.2 Terrace Mining

Terrace mining is a modified method of strip mining, where, due to either the ore body being too deep, or dipping too steeply, a progressive benching method is used to access the deposit. That is to say, the overburden (and sometimes the mineral deposit), are removed in successive, progressive horizontal steps. Due to the extended width of this successive benching, a dragline cannot usually spoil waste material into the adjacent cut’s void. Hence bucket wheel excavators and truck and shovel operations are used to strip the overburden and dump it at the rear of the mining sequence (Bullivant, 1987). See Figure 7.

![Figure 7: Terrace mining.](Source: Bullivant, 1987)

### 2.4.1.3.3 Open Pit Mining

Open pit mining is typically applied to massive dome or pipe deposits such as kimberlite or iron/copper ore or the quarrying of aggregates. The mining is such that benches are stepped down into the deposit in a conical manner using truck and shovel to transport both the waste and ore from the pit. The waste is dumped on a dedicated waste stockpile as it cannot be accommodated within the mining pit (Bullivant, 1987). Figure 8 illustrates a cross-section of such an open pit mine.
2.4.1.3.4 Alluvial and Shore Mining Methods

In brief, alluvial mining is the mining of river sediments; while shore mining may either involve the mining of aeolian dune deposits, or near-seashore, alluvial deposited minerals.

Alluvial mining is the mining of minerals which have concentrated due to the winnowing action (based on density differences) of running river water which has eroded a source deposit. Such a deposit may be called a placer. Gold and diamonds for example may be concentrated in such a manner. Small scale mining of such deposits may be conducted by panning, while large scale alluvial mining entails dredging the riverine environment and/or excavating of the floodplain. These methods result in much vegetation and habitat loss, as well as downstream water quality impacts such as increased silt loads (Hammel et al, 2000; Ramollo, 2011).

Aeolian dune deposits work on the same winnowing principle as alluvial deposits, except that it is the reworking action of winds forming dunes which concentrates the minerals which differ in density to the host material. Diamonds, zirconium, rutile, ilmenite and titanium are examples of such minerals in South Africa (GDACE, 2008). That the mineral rich dune sand may be mined with high-pressure water cannons, topsoil and vegetation removal is necessary. Consequently habitats and hydrology are altered (LaBuschagne, 2007; Maritz, 2007).

2.4.1.3.5 Surface Mining Environmental Impacts

Again, as detailed in Section 2.2.8, Table 2, the potential environmental impacts of mining are numerous. Surface mining’s impacts differ from underground mining in that there is the obvious surface alteration of the landscape. As depicted in the above mining methods, this usually results in the topography and surface drainage patterns being significantly altered, with attendant increases in salt and silt loads in surface water resources. Post-mining scarring is
prominent, in the forms of surface waste rock dumps, ramp scars and final voids. Depending on the mineralogy of the deposit, surface stripping and the exposure to oxidising conditions may result in AMD of surface and underground waters. Surface habitats are significantly altered, fragmented or even destroyed, and post-closure efforts may often not return these to a pre-mining state. Fugitive dust from opencast operations is more problematic than underground mining, with the blasting, loading, trucking, dumping and/or spoiling of ore or waste rock generating significant dust (IFC, 2007a; GDACE, 2008; Twerefou, 2009).

2.4.1.4 Waste Dumps and Tailings

By its very nature, most mining produces large quantities of mineral waste (i.e. uneconomic materials incidental to recovery of the economic mineral). This waste can be broadly categorised as either waste rock dumps or tailings. A waste rock dump is the overburden waste generated by removing overlying layers of soil and rock to gain opencast access to the mineral deposit. Waste rock may also be generated by basic beneficiation; for example sandstones and shales are often separated out from a coal product by basic physical processes (crushing, screening and dense medium separation). That is to say this waste is not substantially processed/altered rock waste (Hudson-Edwards et al, 2011; Wei et al, 2013).

Tailings waste on the other hand, is the waste generated by significant beneficiation and even smelting. The processes applied, both physically and chemically separate the product from the ore. Tailings are often contain a high moisture content, contain additional chemicals used in the beneficiation process, may be acidic or basic in nature and are finely crushed, liberating, mobilising and providing increased reaction potential for other elements contained in the ore (e.g. sulphates, heavy metals). Thus, tailings and waste rock dumps impact on the environment by both the nature of their chemical composition (e.g. AMD, heavy metals) and the physical nature of the dumps (slumping, dam failure, erosion, dust, loss of land use) (Charbonnier, 2001; Ozkan & Ipekoglu, 2002; EC, 2009).

2.4.2 Mine Closure

Due to historical mining and waste management methods, non-accounting of environmental and social impacts, and the ease with which mine sites were abandoned by owners in the past, there exist globally a vast number of legacy mines. That is to say, that despite mining no longer being actively practiced on such sites; environmental and social impacts remain and continue to affect the surrounding environment and communities. Such a legacy is a significant management and financial burden for governments, the public and mining companies; particularly within the discourse of mining aiming to contribute toward sustainable development (Worrall et al, 2009).
Heikkinen et al (2008: 21) defined mine closure as: “... the process, where mine production operations finally cease and the mine owner commences decommissioning the site infrastructure and relinquishes rights to the mining concession”. Mine closure can be planned, or premature and unplanned or catastrophic (Bell et al, 2006). Mine closure can be precipitated by a number of factors: depletion of the ore reserve, a change in the economic viability of the reserve due to changing market conditions, social upheaval, political instability and environmental degradation (Limpitlaw & Hoadly, 2006).

Current literature espouses that in terms of sustainable development, mining must be viewed as a temporary land use and that mine closure must go beyond simply designing for closure, and design for sustainable post-mining land use (Limpitlaw et al, 2005; Robertson & Shaw, 2005; Heikkinen et al, 2008; Vladimir & Tomislav, 2012). However Worral et al (2009: 1427) state that “Despite on-going advances in mine site rehabilitation it is a fundamental reality that many types of mining activity will effectively sterilize some of the land surface from virtually all other use.” Thus grappling with the sustainable closure of mines is a significant hurdle to the ethics, modes and principles of sustainable development.

Worral (2009) goes on to emphasise this by pointing out that the ICMM’s Sustainable Development Principles, the Global Reporting Initiative and the Mining Council of Australia’s Enduring Value, to name a few examples, remain high level in their applicability to mining, are less relevant at operational level, and despite other significant contributions, talk little to sustainable mine closure. Further difficulties complicate mine closure, for example, it is often problematic to anticipate all eventual remediation measures which shall be required, as well as adjusting to the changing legislative expectations over the extended life of a mine (Heikkinen et al, 2008). DME (2007) also, points out that due to environmental impacts generally being considered on a phase by phase basis, the cumulative impacts of mining are often overlooked until they have become a significant problem. Furthermore, due to the disaggregated nature of the issuing of mining authorisations, while one mine may be closing, an adjacent one may be ramping up, creating difficulties in managing environmental impacts regionally. This thus requires, where a lack of government strategy exists, cooperative planning between mining companies (Limpitlaw & Hoadly, 2006).

Nevertheless, it has come to be generally accepted that, throughout the life cycle of a mine, mine closure must iteratively be planned, reviewed and appropriate actions taken if said closure is to prove successful and sustainable (MMSD, 2002; Limpitlaw, 2004b; Robertson & Shaw, 2005; Bell et al, 2006; IFC, 2007a; Stacey et al, 2010; Hodge, 2012; Vladimir & Tomislav, 2012).
Figure 9, adapted from Bell et al (2006), depicts how mine closure planning is necessary at every stage of mining and such that sustainability principles are effected throughout.

If such iterative closure planning and attendant actions are implemented from the outset, then the final closure liability (legacy) will be minimised and closure objectives more likely to be met. Figure 10 depicts the consequences of such progressive closure planning practice versus weak closure planning in which unforeseen closure risks and thus costs arise at the end of the life of mine (ICMM, 2006).
Limpitlaw & Hoadly, (2006) maintain that during and post-closure, the ultimate outcome of a mine’s contribution to sustainable development, be it positive or negative, is put to the test by post-closure monitoring. This again reinforces the relevance of this study: that of developing environmental sustainability indicators in support of sustainable mine closure. If progress toward the environmental facet of sustainable development is better measured throughout the mine life cycle, then the ultimate stage of mining, closure, can be directed towards leaving a positive legacy.

2.4.2.1 Environmental Impacts and Objectives of Closure

To better locate mine closure within the discourse of sustainable development, a little more needs to be discussed about the environmental aspects and impacts of mine closure. The detailing of the social aspects of mine closure are however beyond the remit of this study. The literature reviewed provided many categories of issues associated with mine closure. It must also be noted that it is the environmental impacts summarised by mineral in Section 2.2.8, Table 2, which tend to persist beyond the operating life of the mine. Hence in this section, rather than unnecessarily re-enumerating these impacts, board categorisations, espoused in the literature, of mine closure’s impacts and environmental legacy are put forward.
Robertson & Shaw (2005), categorise potential closure impacts to be dealt with as:

- Physical stability – unstable structures, surface subsidence, tailings collapse and erosion of slopes.
- Geochemical stability – minerals, metals and other contaminants may be unstable and at hazardous concentrations, and can affect the surrounding environment via pathways from the site. Water pollution (AMD) and waste dump dust are examples of this.
- Land use – rehabilitation should be consistent with pre-mining use, surrounding or planned and sustainable post-closure land use. Such rehabilitation should support self-sustaining ecosystems.
- Sustainable development – post-closure, economic and social impacts and considerations should be integrated such as to leave a positive legacy.

MMSD (2002), IFC (2007a) and Heikkinen et al (2008) go on to speak to the desired objectives of closure:

- Physical stability – All remaining structures, from buildings and plant to dumps and pits to shafts and underground workings must be physically stable and safe into the long term. Of particular import is that erosion be mitigated.
- Chemical stability – The site remains chemically stable and does not affect the surrounding environment via diverse vectors. Soil and water quality (surface and underground), meet the sustainable environmental standards of the area.
- Biological stability – Allows for natural and balanced ecosystem reestablishment.
- Geographical and climatic influences – Closure is appropriate to the range of climatic influences and the geography of the area.
- Land use and aesthetics – Closure enables the productive and economical post-operational land use following the principles of sustainable development.
- Natural resources – Closure aims at securing the amount and quality of the natural resources of the site.
- Financial consideration – Adequate funds are available for closure and are readily accessible.
- Socio-economic issues – The surrounding community is consulted and included in closure decision making and a positive socio-economic legacy remains.

Which ultimately support sustainable mine closure goals (MMSD, 2002; IFC, 2007a; Heikkinen et al, 2008):

- Reverting to a premining state;
- And/or the securing for any future land use;
- Allowance for the establishment of diverse ecosystems;
- The future public health and safety are not compromised;
• Environmental resources are not subject to physical and chemical deterioration;
• The after-use of the site is beneficial and sustainable in the long term;
• Any adverse socio-economic impacts are minimised; and
• All socio-economic benefits are maximised.

It is through developing indicators which speak to these sustainability principles and objectives that the trajectory of a mine’s contribution to sustainable development can be measured and thereby managed. This process must be iterative and imbedded in the mining life cycle so as to appropriately influence management decisions timeously. Thus by the end of life of mine, the actual state of the site is closely aligned with the site specific and sustainable objectives of closure.

2.4.2.2 Mine Closure in South Africa

Mine closure in South Africa is a contentious issue both socially and environmentally. On the social front, mine workforce and unions are demanding mines remain operational along with higher wages, with devastating consequences such as the 2012 Marikana tragedy (Marikana Commission of Inquiry, 2014). Furthermore there is a national debate and uncertainty regarding the nationalisation of mines and the consequent passing of closure responsibility and liability on to the state (Bauer, 2012). This is notwithstanding, as already mentioned, South Africa having “in excess of five thousand ownerless and derelict mines” (DME, 2007: 63), whose estimated liability to the state is R1.6 billion over 10 years, but ultimately would require a conservative estimate of R30-billion for environmental restoration (Baartjes & Gounden, 2011).

On an environmental front, acid mine drainage, especially recently in the Witwatersrand due to mine closure, has become a controversial topic with arguments over the apportioning of responsibility (often financial) for this historical legacy of cumulative impacts. Radioactivity and dust from mine dumps, the use and pollution of scarce water for fracking, and heavy metals in AMD decant have also been highlighted as serious environmental problems and received media attention (Expert Team of the Inter-Ministerial Committee, 2010; McCarthy, 2011; News24, 2012a; News24, 2012b, News24, 2014a). These environmental impacts negatively affect ecosystems, their carrying capacity and efficacy in delivering ecosystems services, as well as the (often impoverished) surrounding communities (van Eeden et al, 2009). With these aspects considered as well as those of a declining resource base, the volatility of the South African currency and unpredictable global resources prices, the continuation of ‘business as usual’ mining in South Africa is strained on numerous fronts (Fin24, 2012; Greve, 2012). Furthermore with current legislation in place however, mine owners can be held liable for all closure costs (DME, 2002). This puts the mining industry in an untenable situation if closure is not closely planned and properly managed, and adequate financial provision consequently
not made to mitigate legacy impacts. Criminal litigation may come to be pursued by the state or civil society pressure groups (Humby, 2012). This again highlights the relevance of such research into indicators of sustainable mine closure in the South African context.

2.5 SUSTAINABLE DEVELOPMENT INDICATORS

2.5.1 Indicators of Sustainable Development

With the advent of the concept of sustainable development and the practices adopted and driven by it, the need for indicators arose, to measure progress towards (or away) from the tenants of sustainable development. Most major mining companies have adopted policies which include sustainable development as a goal (Worrall et al., 2009, MTF, 2010). Hence information is required on the economic, environmental and social facets of the company (the three pillars of sustainable development) so that informed decisions may be made in line with such a goal.

MTF (2010) and Van Cauwenbergh et al (2007) state that, across resource sectors, a widely used and most versatile model for measuring such sustainability progress is the use of principles, criteria and indicator frameworks. The sustainability in mining principles described in Section 2.3.5 and the closure objectives in Section 2.4.2.1 are the foundation for such a model. Criteria are more specific objectives which describe the actual real world conditions which society seeks in order to achieve the goal of sustainable development (MTF, 2010; Van Cauwenbergh et al, 2007). With criteria being more concrete and achievable, they can be associated with measurable indicators, which in turn serve to determine or assess the progress toward (or away) from said same criteria, and thereby sustainable development.

This leaves the question of rigour when aiming to select useful indicators. Numerous selection principles for indicators have been developed, namely that indicators should be (Segnestam, 2002; Worrall et al., 2009; MTF, 2010):

- Measurable and clearly defined,
- Cost effective,
- Measurable over time,
- Sensitive to change,
- Scientifically valid and meaningful,
- Based on functional ecological relationships,
- Direct relevance to objectives,
- Direct relevance to the target group,
- High quality and reliable.
In this manner, indicators seek to provide a measure of the change in a criterion over time. By measuring states and summarising data, indicators should function as a descriptive tool that enables assessment. In fact, an indicator’s meaning must extend beyond its own measure and seek to provide an understanding of the larger criteria of interest. This often requires some form of analysis (Segnestam, 2002), as an indicator does not necessarily describe the reasons for its indication of change. Ultimately, the information gained from the understanding of an indicator’s indication of a criterion’s condition should lead to informed decision making and action. However, as Bossel (2001) and Van Cauwenbergh et al. (2007) warn, getting the right number and mix of essential indicators is a difficult task. There is no perfect set of ‘applicable-across-the-board’ indicators. Too few indicators, and aspects of a system may be overlooked and unanticipated changes may result. Too many indicators, and the data becomes unwieldy to manage and the clarity of the indicators’ message may be obscured.

The first step in developing indicators is that of developing a framework. Indicator frameworks serve a number of purposes, namely: a structure to facilitate interpretation of the indicators, a methodology to comprehensively cover all aspects of interest and assign them indicators, and lastly provide a conceptual model for understanding and interpreting the interrelatedness of the issues at hand Segnestam (2002). Van Cauwenbergh et al., (2007) describe two main types of indicator frameworks: systems-based and content-based. Systems-based indicator frameworks use key attributes and describe the general behaviour/sustainability of a system as a whole. However these systems indicators tend to be qualitative due the complexity of systems. Also an extensive knowledge is required of the system to derive meaningful indicators. Such frameworks tend to be used at a higher, macro level of analysis (e.g. national or corporate business level). Content-based indicators on the other hand seek to describe specific aspects of a system (often related to a function or process of that system). This specificity allows for easier formulation of objectives and targets to manage the aspect. However it does not translate easily into a holistic picture of the system, its context and its sustainability itself. Content-based frameworks tend to be more applicable to the project or ground level Bossel (2001).

This raises a cross-cutting issue with indicators, namely scaling and use: indicators applicable at mine level may not be useful at national level, and problems may be encountered in aggregating them without losing important detail. Having a core set and a more comprehensive detailed set of indicators can go some way in addressing this issue of scalability. The OECD (2004) has sought to define a number of classes of indicators to address the use and range of indicators adapted by their member countries. ‘Core environmental indicators’ track environmental progress, while a ‘key set’ is used to communicate to the public. ‘Sectoral indicators’ are also used (e.g. energy, transport etc.) as well as ‘environmental accounting indicators’ with an economic aspect. ‘Alarm indicators’ can also be used as early warnings to initiate, investigate and monitor more detailed diagnostic indicators (Segnestam, 2002). However there is no easy solution to these problems of fit-purpose and scale; thus the
cognisance thereof is important when formulating an indicator set, such that it may be taken into account in light of the goal (and target audience) at hand.

2.5.2 Practical Considerations of Indicators

Poor data quality and insufficient data availability are very frequent problems encountered, especially at higher levels of monitoring. Further issues encountered are: resource constraints for indicator monitoring, aggregation and comparison difficulties, poor central data management, gaps in monitoring networks (spatial and temporal), the use of estimates to fill gaps, difficulties in conceptualising the measures of a system, the aggregation of dissimilar data, low priority and/or institutional will (Segnestam, 2002). With these problems in mind, it can be seen that the comprehensive (spatial, temporal and subject) development of indicators is something which takes time, priority and resources. Hence all available data must be used with the greatest efficiency possible and proxies considered if initiating new indicators is not immediately feasible. Segnestam (2002) goes on to suggest that local stakeholders can be included and motivated to assist in data collection so as to minimise the costs of hiring contractors. This also fosters buy-in to the sustainability of the project at hand. There are further issues when it comes to the actual data collection such as credibility, cost effectiveness and capacity, but these data collection issues and others are beyond the scope of this study.

2.5.3 Considerations in Formulating an Indicator Set

As becomes obvious from this brief review of sustainable development indicators, there is much to consider when devising an indicator set. Due to the broad nature of the notion of sustainable development and this research (as opposed to a project specific case study), the systems approach to indicator development will be followed in meeting the objectives of Section 1.2. The sustainability principles defined in Section 2.3.5 shall be used as an indicator framework, while the objectives of closure (Section 2.4.1.2) used as criteria; consequently, linked environmental sustainability indicators will be developed (see Table 9 in Section 5.3.1). The primary target audience would be those involved in the mining industry, such that the indicators may be used to aid decision making. Moreover, the progress that these indicators attest to, can be utilised in public reports to espouse the headway made towards sustainable mine closure.
2.6 SOUTH AFRICAN MINE CLOSURE LEGISLATION

2.6.1 Introduction

The mining legislative landscape in South Africa is a hotly debated topic at present both in the media and literature. Due to certain amendment bills and acts, there is a lack of clarity regarding the handling of the environmental aspects of mining and mine closure (van Eeden et al, 2009; Blaine, 2013; CSA et al, 2013; Seccombe, 2013; Humby, 2014). Nevertheless, for the purposes of this study, the loopholes, responsible government authorities and transition periods will not be considered of prime material import; as the maze runs too deep, too detailed and continues to shift. Rather, the substantive intent of the Acts and Amendments will be considered, with the view that the legislative landscape will be steered toward the best possible outcome for sustainable development which South Africa’s highest law, The Constitution mandates, and thus all subordinate legislation must abide by.

2.6.2 The Mineral and Petroleum Resources Development Act

The Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) is the primary legislation which governs mining activities and mine closure and is administered by the National Department of Mineral Resources (DMR), previously known as the Department of Minerals and Energy (DME) (DME, 2002). This act has most recently been amended by: The Mineral and Petroleum Resources Development Amendment Act 49 of 2008, which was enacted on 7 July 2013. However, there is currently another MPRDA Amendment Bill before parliament as of 31 May 2013. This bill is controversial and may only be fully enacted by June 2016 (Humby, 2014; Odendaal, 2014).

Upon closure, the MPRDA contains the requirement for an application by the mine owner for a closure certificate (to be issued by the DMR). Until such a certificate is issued, as per Section 43 (1), the mine owner “remains responsible for any environmental liability, pollution, ecological degradation, the pumping and treatment of extraneous water, compliance to the conditions of the environmental authorisation and the management and sustainable closure thereof”. However the current MPRDA Amendment Bill goes on to state “remains responsible for any […] notwithstanding the issuance of a closure certificate”. Hence this places near indefinite responsibility on the holder of the mining right for any environmental aspects of closure (DMR, 2013).
Financial liability for environmental consequences of closure and provision therefor by the mine owner is also required by the MPRDA. As per Section 43 (6), upon issuance of a closure certificate the DME must “return such portion of the financial provision […] as [the DMR] may deem appropriate […] but may retain any portion of such financial provision for latent and residual safety, health or environmental impact which may become known in the future”. However the current MPRDA Amendment Bill appears less stringent in that it adds to this “for a period of 20 years after issuing a closure certificate”. It has been argued that environmental impacts may only become apparent much longer than 20 years after the issuing of a closure certificate, and that the DMR should be able to retain any portion of the financial provision well beyond an arbitrary 20 years (CSA et al, 2013).

In 2005 the DMR (then DME) brought out the Guideline Document for the Evaluation of the Quantum of Closure-Related Financial Provision Provided by a Mine (Naudé & Cornelissen, 2005). As for its legal standing, only Section B constitutes a guideline document as contemplated in regulation 54(1) promulgated in terms of the MPRDA, 2002. Of import and relevance to this study is Table B.12: Primary risk class for type of mineral mined/processed. This table assigns specific minerals into High, Medium and Low risk. Classes A, B and C respectively. See Table 1 (Section 2.2.8). Coal is considered class A across all contexts. Diamonds and platinum are classed as either B or C depending if the mine includes processing facilities or not. Gold is classed as A or B, again depending if ore processing takes place on site. Furthermore, regardless of mineral, underground mines are rated at the very least as class B. Thus this study includes a representative spread of minerals across these primary risk categories.

The MPRDA also goes on to provide for cooperative governance in the approval of a closure certificate (DME, 2002). That is to say, as per S43(5) of the MPRDA, the DMR is required to consult and gain the approval of a closure certificate from: “each government department charged with the administration of any law which relates to any matter affecting the environment […] that the provisions pertaining to health and safety and management pollution to water resources, the pumping and treatment of extraneous water and compliance to the conditions of the environmental authorisation have been addressed”. These most notably are The National Departments of Environmental Affairs (DEA) and Water Affairs (DWA) and the Council for Geoscience (CGS) (DME, 2002). The MPRDA, in S43(9), does provide a mechanism for the DMR, in conjunction with DEA, to publish “strategies to facilitate mine closure where mines are interconnected, have an integrated impact or pose a cumulative impact.” However to date, no such strategies appear to have been published.
The MPRDA also requires a mine closure plan to manage and implement such procedures as defined by the DMR (currently prescribed in the MPRDA Regulations: GN R527). GN R527 puts forward certain environmental principles for mine closure (DME, 2004):

- Mine closure must be planned for and managed throughout the life cycle of the mine.
- Environmental risks must be continuously identified and managed proactively throughout the mine life cycle – this includes gathering relevant environmental monitoring data.
- Residual and latent impacts environmental must be identified and quantified.
- The land is rehabilitated, as far as practicable to its original state; or some pre-agreed state which conforms with the tenants of sustainable development
- That closure is done efficiently and cost effectively.

Furthermore the environmental management plan of the mine must include the key objectives of mine closure so as to guide mine design, operation and management of environmental impacts; this includes broad land use objectives for the site and proposed closure costs. Upon applying for a mine closure certificate, GN R527 requires that a prescribed closure plan, environmental risk report and final performance assessment report are submitted.

The risk report must identify all possible environmental risks, including those deemed insignificant. Through an iterative process, all such risks, including uncertain risks, must then be rated as significant or insignificant, and their classification validated based on actual monitoring data. Management measures must then be developed and applied to each significant risk. These management measures must include: the long term expected results after application, the residual and/or latent impacts after the measures have been applied, the timeframes and long term responsibility for implementation and on-going management, the financial provision for said measures, and importantly the implementation of a monitoring program/s. The mine closure plan must additionally include: records of public participation conducted, a report on the progressive rehabilitation undertaken, descriptions of the methodology for decommissioning aspects of the mine, details of long term maintenance, and the financial provisions for monitoring and post-closure management and any other supporting technical documentation (DME, 2004). Thus it can be seen that legislated mine closure in South Africa rigorously abides by sustainability principles.

2.6.3 Other Applicable Legislation

Part of the difficulties of the South African legislative landscape is that the environmental impacts of mining and mine closure also fall within the remit of other environmental laws and responsible government authorities. Primarily, and as previously mentioned: The National Departments of Environmental Affairs (DEA) and Water Affairs (DWA). The MPRDA further states, as per Section 43 (8), that any mine closure requirements must also be adhered to as
prescribed in terms of the National Environmental Management Act, 1998 (DME, 2002). Thus, mining falls somewhat both under NEMA and MPRDA. As of yet there is no alignment or streamlining between these departments and legislations as to the procedures and applications required for the authorising/management of the environmental impacts of mining and mine closure (CSA et al, 2013).

DEA administers the National Environmental Management Act 107 of 1998 (NEMA), which was last amended by the National Environmental Laws Amendment Act 25 of 2014 (DEAT, 1998; DEA, 2014a). Not all of the provisions of this amendment act with respect to mining have been ‘activated’. However as per a media statement by DEA, the amended provisions regarding mining will take effect on 8 December 2014 (DEA, 2014b). As previously noted, due to the complexity and unstable nature of this legislative landscape, a high level of contemporary and easily out-dated detail, has been avoided.

The Department of Water Affairs (DWA) (Previously DWAF – Department of Water Affairs and Forestry) administers the National Water Act 36 of 1998 which was last amended by the National Water Amendment Act 45 of 1999 (DWAF, 1998; DWAF, 1999). This remains fairly straight forward in that Section 19 (quoted below), is the portion of legislation the DWA may use to ensure that mine closure is adequate and does not cause water pollution:

**S19. Prevention and remedying effects of pollution**

1. An owner of land, a person in control of land or a person who occupies or uses the land on which:
   (a) any activity or process is or was performed or undertaken; or
   (b) any other situation exists, which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.

2. The measures referred to in subsection (1) may include measures to:
   (a) cease, modify or control any act or process causing the pollution;
   (b) comply with any prescribed waste standard or management practice;
   (c) contain or prevent the movement of pollutants;
   (d) eliminate any source of the pollution;
   (e) remedy the effects of the pollution; and
   (f) remedy the effects of any disturbance to the bed and banks of a watercourse.

In this, the DWA is guided by the *G5 Best Practice Guideline: Water Management Aspects for Mine Closure* (DWAF, 2008).
2.6.4 Conclusion

Despite the current legislative morass in which the environmental aspects of mining are mired, sustainable development principles are well embedded in South African mining and closure legislation. Primarily, all South African law is subordinate to The Constitution which provides for sustainable development and environmental protection under Section 24 as previously quoted in Section 1.1 of this dissertation (RSA, 1996). The mining and applicable environmental laws (see Sections 2.6.2 and 2.6.3) which stem from this, go further and espouse the following applicable principles (DEAT, 1998; DWAF, 1998; DME, 2002; DME, 2004):

- Precautionary principle
- Polluter pays, financial liability
- Sustainable closure
- Management by environmental risk identification and rating
- Cooperative governance and stakeholder engagement
- Cumulative impacts
- Lifecycle planning to include closure at all stages
- Environmental monitoring
- Sustainable rehabilitation
- Cost effective closure

Though less detailed, mostly broad, and not as comprehensive, these tenants and modes in South African legislation applied to mining and mine closure, are reasonably well aligned with the global thinking around sustainable development as detailed in Table 3 (Section 2.3.5).

Nevertheless there are some weaknesses in the South African legislation with regard to the aforelisted principles. The ‘Subsidiary Principle’ for example is not explicitly mentioned; this could strengthen public participation and cooperative governance if clearly prescribed. Again tacit in the legislation is the concept of addressing mining, the environment, the public, and financial implications as an interrelated system. Public reporting and transparency is another facet of sustainable development which is not specifically emphasised in the South African legislation under discussion; although reports to government are required in most all mining licences and the Promotion of Administrative Justice Act (Act 3 of 2000) and Promotion of Access to Information Act (Act 2 of 2000) also seek to address this (PAJA, 2000; PAIA, 2000).

Lastly there is no mention of considering the mitigation of climate change as a driver for sustainable development. This is not an exhaustive review, as due to the overlapping nature of sustainable development principles, only conceptual gaps can be pointed out in all fairness. Nevertheless it can be said, that despite the aforementioned partial gaps, that sustainable development is robustly included in South African mining and closure legislation. A more detailed gap analysis of the ratification of these sustainability principles’ ratification in South African environmental legislation is presented in Table 8, Section 5.2.
However there are other issues facing sustainable closure in South Africa. According to Munnik & Pulles, (2009: 6) weak cooperative governance between government departments, as well as the lack of technical capacity to adequately assess sustainable closure has resulted in a mine closure certificates not being issued, as illustrated in their example: “In order for a mine to obtain a closure certificate from the Department of Mineral Resources (DMR), the DWA must confirm that the potential pollution of the water resources has been addressed satisfactorily. Due to the fact that there was [historically] no guideline to assist the authorities in making a decision, a situation developed where mine closure was perceived to be unattainable or impossible.”

Thus, despite sustainability principles being embedded in applicable mining and environmental legislation, there are other institutional and contextual issues which hamper sustainable closure. These issues are further exposed and discussed in the results of this study’s survey (Chapter 4).

2.7 CONCLUSION

The crux of this research lies at the intersection of sustainable development policy and mine closure; and environmental indicators which could evaluate this intersection. That is to say: toward the measurement of sustainable closure progress. Thus this conclusion to the literature review seeks to reposition these themes in direct relation to each other, and synthesise said literature, such that a robust and nuanced context exists for the discussion of the results of the study (Chapter 4).

2.7.1 A Synthesis: The Intersection of Sustainable Development Policy, Mine Closure and Indicators

With the above literature reviewed and discussed, it can be seen that although there has been much work on investigating and locating mining’s role within sustainable development (with the inclusion of closure considerations), and consequently developing guiding policy and legislation therefrom, there has been little by way of measuring the trajectory of the implementation of such principles and policy. That is to say, there has been little to no discussion on measuring how a mine’s operational activities specifically impact on sustainable environmental closure – i.e. the intersection of mine closure, sustainable development and environmental indicators. See Figure 11 below.
Were the measurement of the environmental aspects, of the impacts of mine closure, against the ultimate goal of sustainable closure, to be actively measured throughout the life cycle of a mine, it stands to reason that management decisions would be better informed to direct the ultimate closure of mines toward a positive and sustainable environmental outcome. It must be pointed out that all mines eventually close; and that in this era of striving toward the goal (and necessity) of sustainable development, the end game of mining, closure, must be focused upon to ensure the leaving of a sustainable legacy. Over the usually significant life spans of mining operations, were such a set of sustainable mine closure indicators to be continuously measured, mining operations could be proactively steered towards the mine ultimately contributing to sustainable development, both during and after its operating life.

Figure 11: Venn diagram representing the key elements of this study.
CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

There is much theory and discussion around mine closure, as has been evidenced in the preceding chapter. However there is also a very definite ‘on-the-ground’ aspect which is acutely practical in its considerations and implementation. This dissertation posits the research need to determine the gap(s) between mine closure policy, legislation and the ‘on-the-ground’ status quo in South Africa (see Section 1.2). It was decided that this real world ‘state-of-play’ could best be measured by surveying practicing mine closure professionals. Thus a web-based questionnaire was drafted, sent to a list of 159 professionals with South African mine closure experience, and the responses qualitatively aggregated (see Results and Discussion Chapter 4). This chapter shall discuss the methodology used in designing, disseminating and encouraging responses to the questionnaire.

3.2 QUESTIONNAIRE DESIGN AND DISTRIBUTION

3.2.1 Questionnaire Design Theory

Labaw (1980) put forward that the greatest weaknesses in questionnaire design was the lack of application of systematic theory. Thus this dissertation sought to take this notion into account, and design the questionnaire (used to collect the opinions and experience of mine closure professionals), using Labaw’s three types of (theoretically) objectively measurable predictor variables. These three variables are namely (Holdershaw et al, 2006; based on Labaw, 1980):

1. Questions regarding relevant aspects of the respondents’ environment,
2. Questions regarding their knowledge about the subject of interest,
3. And questions regarding current and past behaviour.

Thus, it was deemed rigorous to follow questionnaire design theory and make use of Labaw’s aforementioned framework. Questions could be asked of a respondent regarding the mines, their size and mining method (environment); questions posed regarding ideal indicators, best practice and recommended studies (knowledge); and lastly, questions tailored to interrogate actual practices of mine closure in South Africa (behaviour). Thus this framework was found to be an appropriate fit for this study and the objective of determining the status quo of South African mine closure. The questionnaire was thus broadly structured accordingly.
Regarding the binary approach of utilising open-ended vs. closed-ended questions, Reya et al (2003) and Choi & Pak (2005) provided useful guidelines and commentary to this effect; particularly in the application of web-based questionnaires (as used in this dissertation, see Section 3.2.4). The research of Reya et al (2003) specifically found that open-ended questions, despite generating more ‘missing data’ or inadequate answers, allowed for a wider variety of answers. It was thus decided that for this study, in determining the status quo of mine closure, that it was preferable that experts responded with the breadth of their knowledge on mine closure practices, rather than testing predetermined notions in this uncertain and complex applied field. Nevertheless, in specifically testing the respondents’ knowledge of South African mine closure legislation, closed-questions were used. Due to the open-ended nature of most of the survey questions, the responses were interpreted by means of a qualitative narrative with quantitative analysis where possible (See Results and Discussion Chapter 4).

Further general principles to adhere to when designing a questionnaire are advocated by Gendall (1998), also based on Labaw’s work. For example, regardless how objective the questionnaire designer has endeavoured to be, their ‘view of the world’ will be enmeshed in the questionnaire. Hence above and beyond the researcher being aware of this, respondents should be encouraged to answer with what they mean, rather than the researcher’s values, perceptions and language being imposed on them. This maxim was thus borne in mind during the designing of the mine closure questionnaire and again supported an open-ended question approach.

Another important general principle which Gendall (1998) puts forward, is that the prime focus of a questionnaire must be the objectives thereof. That is to say, knowing exactly what information the researcher wishes to lift from the responses to the questionnaire. In the instance of this dissertation, these objectives were determined to be the following:

- The level of mine closure experience of the respondents,
- Metadata regarding the businesses, operations, mineral and scale of mining they are involved in,
- The current status quo of mining’s environmental indicators and mine closure practices,
- Current and ideal best practices in mine closure.

In the processing and collating of the survey’s responses, each question was assigned one of these objectives, and thus the desired research objectives were rigorously solicited accordingly.
3.2.2 Questionnaire Tailoring

Initially a draft questionnaire of approximately twenty questions, designed to address the aforementioned objectives, was compiled. This initial questionnaire was then tested and approved by Dr. Fethi Ahmed, the supervisor of this dissertation, as well as passed through the University of Johannesburg’s ethic’s clearance procedure. It was at this point then decided that, due to the range of professional sectors from which respondents were likely to operate, that six broad sectors be defined and the initial questionnaire tailored accordingly. These six sectors were determined based on reviewing respondents’ work experience as provided by their LinkedIn profiles (LinkedIn, 2014). This is supported by Dillman et al’s (2009: 16) Tailored Design Method which: “involves using multiple motivational features in compatible and mutually supportive ways to encourage high quantity and quality of response to the surveyor’s request. [And] it assumes that the likelihood of responding to a self-administered questionnaire, and doing so accurately, is greater when the respondent trusts that the expected rewards will outweigh the anticipated costs of responding.”

Thus, the questionnaire was tailored to six professional sectors in which respondents were likely to operate from, namely:

- Mining site – respondents who work for a mining company and are involved in mine closure on the mine site (usually more practical/operational).
- Corporate - respondents who work for a mining company and are involved in mine closure at a divisional or head office level (usually more strategic/management).
- Academic – respondents who are employed as academics and are involved in often longer term mine closure research and trials.
- Consultancy – respondents who work for a consultancy firm which offers mine closure services and expertise to mining companies (often on a short term or project basis).
- Governmental – respondents who work for government departments and their remit includes dealing with mine closure.
- Legal – respondents who have a legal background and advise mining companies on legal matters pertaining to closure.

Tailoring the questionnaire accordingly, produces better quality of data, as well as maintaining the questionnaire’s relevance to a respondent’s work experience – and thereby ensuring the respondent is not asked irrelevant (and thus deterring) questions. Furthermore, the manner of distribution, follow up and offering a copy of this final dissertation to respondents also takes cognisance of Dillman et al’s (2009) Tailored Design Method. However this shall be discussed in Section 3.2.5 (Distribution, Follow Up and Responses). Lastly, a version of the final survey was piloted with six personal contacts; one from each professional sector category. Their comments on the questions were then integrated into an improved final tailored questionnaire (See Appendix A).
3.2.3 Garnering Respondents

The author of this dissertation has over ten years of professional environmental management experience, including mining and mine closure activities. Thus, as an initial departure point for garnering respondents, mine closure professionals known to this researcher were contacted and asked if they would participate in a mine closure survey; and furthermore if they could identify and recommend any other such professionals. This method of respondent gathering is termed the snowball method (Biernacki & Waldorf, 1981; Faugier & Sargeant, 1997). Thus a preliminary list of respondents was developed. The overriding criterion for including a respondent in the list to which the final questionnaire was to be sent was that: respondents have some form of mine closure experience. The determination of this criterion was based on either: a referral from an existing respondent with mine closure experience, or on their professional profile on the LinkedIn network (LinkedIn, 2014). Respondents had to also either currently be working in the South African mine closure field, or had done so in the past. This method of leveraging personal networks and consequent referrals produced an initial list of almost 70 experts.

Subsequently it was deemed advantageous and expedient to make use of the LinkedIn professional networking website (www.linkedin.com) to increase the number of identified specialists who would participate in the survey. Using the search functions, professionals meeting the criterion of having South African mine closure experience were first invited to ‘connect’ on LinkedIn. That is to say, accept the sharing of contact and profile details according to the LinkedIn privacy framework. Once an individual accepted this invite to connect, they were sent a courtesy email thanking them for their willingness to participate in the survey, as well as some background to the study and its aims. This was intended to engender both trust and buy-in to participating in the survey. In addition, a privacy statement assuring respondents that their personal details would not be shared or published was included. Once a total list of 159 professionals had been contacted in the above manners, an email with a web link to the survey sent out to all. South Africa is a country in which skills are scarce, with environmental engineers and managers in particular placed 35th and 80th on the National Scarce Skills List respectively (DHET, 2014). It was thus deemed that the total number of participants (the sample) approached the population of the niche field of mine closure experts in South Africa, and was thus representative of mine closure practices and opinions.

3.2.4 Electronic Web-based Questionnaire Design

It was decided to administer the questionnaire via email and by using an online survey tool. Various web-based survey platforms were researched, with the free-versions of the following five options shortlisted, and their pros and cons weighed up as per Table 4 below.
Table 4: Benefit analysis of freely available web-based survey tools.

<table>
<thead>
<tr>
<th>Survey Tool</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **SurveyMonkey** | • Popular  
• Easy to use  
• 15 question types  
• Basic themes  
• Charts and basic statistics  
• Send survey link and track responses using tool | • 10 question maximum per survey  
• 100 responses maximum per survey  
• Only view responses online, no export of data to MS Excel  
• No skip logic and question piping |
| **QuestionPro** | • Easy to use  
• 15 question types  
• Send survey link and track responses using tool  
• Charts and basic statistics | • 12 question maximum per survey  
• 100 responses maximum per survey  
• Only view responses online, no export of data to MS Excel  
• No skip logic and question piping |
| **Google Forms** | • Unlimited questions  
• Unlimited responses  
• Skip logic and question piping  
• Automatic export to MS Excel  
• Graphing and statistics with MS Excel | • Less straightforward to setup questionnaire  
• No charts or statistics  
• Cannot send survey link and track responses using tool – manual response tracking  
• Only 7 question types |
| **SurveyGizmo** | • Easy to use  
• Unlimited questions  
• Export to MS Excel  
• Charts and basic statistics  
• Basic themes | • 50 maximum responses  
• Only 8 question types  
• No skip logic and question piping  
• Cannot send survey link and track responses using tool |
| **LimeSurvey** | • Powerful customisation  
• Open-source  
• Unlimited questions  
• Unlimited responses  
• 28 question types  
• Skip logic and question piping  
• Send survey link and track responses using tool  
• Export to MS Excel  
• Charts and basic statistics | • Steep learning curve (open-source programmable)  
• Requires deployment on a web-server |

# The surveys can be found at: SurveyMonkey [www.surveymonkey.com](http://www.surveymonkey.com); QuestionPro [www.questionpro.com](http://www.questionpro.com); Google Forms [www.google.com/googled-s/createforms.html](http://www.google.com/googled-s/createforms.html); SurveyGizmo [www.surveygizmo.com](http://www.surveygizmo.com); LimeSurvey [www.limesurvey.org](http://www.limesurvey.org).
Considering Table 4 above, certain factors were primary considerations for the research being undertaken. While the number of question types (e.g. tick box, ranked answers, text box, radio buttons etc.) varied widely across the five online survey tools appraised, this was not a critical factor. The mine closure questionnaire which had been designed consisted chiefly of open-ended questions requiring a text box input, in addition to a number of tick box questions which all the survey tools provided. For same reasons charting and statistical analyses were not of prime importance.

The more important factors needed to be considered were: limits on the number of questions and respondents, as well as the possibility of question piping, skip logic and the export of data. Since there were to be six tailored questionnaires, skip logic and question piping was imperative. That is to say, based on the selection of one of the six pre-defined professional sectors at the start of the questionnaire, the survey tool can skip and pipe the respondent to differing (tailored) questions. Further to this, with the survey going out to 159 respondents, and the questionnaire containing up to 19 questions, it was not negotiable that the free versions of these survey tools be limited to below these numbers. The exporting of data was also a desirable factor such that the data could be interrogated with ease. Thus due to question and respondent limits, lack of question piping and skip logic, and the inability to export raw data to Microsoft Excel: SurveyMonkey, QuestionPro and SurveyGizmo were excluded from possible use. It must be said however that the integrated survey sending, tracking and management available in SurveyMonkey and QuestionPro would have proven useful.

With the above three tools excluded due to the non-negotiable limiting factors detailed above, the choice came down to Google Forms and LimeSurvey. LimeSurvey is a very powerful and customisable online survey tool. However it is not hosted independently online as with the other tools. That is to say, it is required that it is installed on a web-server and hosted online by the user. With a lack of resources and expertise to achieve this, LimeSurvey was consequently discarded as a viable option. This resulted in Google Forms being selected as the online survey tool with which to administer the questionnaire. Google Forms met all the non-negotiable requirements and only fell short with the ‘nice to have’ of being able to automatically manage and track participants’ completion of the questionnaire.

The Google Forms survey was setup such that the first page provided both a background to the study and an explanation as to how to complete the online survey. Moreover, on this initial page, there were three required questions (i.e. the participant may not proceed without these three questions being answered). These were namely, the respondent’s name, company and which of the six aforementioned sectors their mine closure experience lay in. The first two allowed correlation with, and tracking of, the contact list previously drawn up; while the last directed the respondent to the questionnaire appropriately tailored to their working sector. For each of the six sectors there were approximately seven pages to the survey with two to five questions per page. Most all questions were of an open text box type, with only the knowledge
of South African mine closure legislation being tested with a tick box type question. The last page thanked the participant for their time and expertise, and asked if the respondent would appreciate a copy of the final dissertation upon its completion.

3.2.5 Distribution, Follow Up and Responses

Archer (2007) states that: “Some factors that have been found to increase [web-based] response rates include: personalized email cover letters, follow-up reminders, pre-notification of the intent to survey and simpler formats.” Thus these factors were leveraged in this study in an attempt to increase the response rate.

After the initial ‘intent to survey’ contact (previously described in Section 3.2.2) and the first circulation of the questionnaire by email, respondents were again contacted on three more occasions, each approximately a month apart, if they had not yet already completed the survey. The emails were addressed directly by name to the respondent to encourage their response, and if a telephone number was available, they were also contacted telephonically to again request and motivate their participation. After three unsuccessful follow-ups it was deemed that a respondent was unlikely to respond regardless, and they were marked as a non-responder. The final number of responses was 56 out of a total 159; this represents a 35% response rate. A limitation of this study could be seen to be the relatively low response rate and the consequent low number of total respondents. This may be attributable to insufficient time available on the part of these closure professionals. However due to all respondents having a definite level of expertise in mine closure this was deemed as an acceptable shortcoming considering the context of South Africa as a skills scarce country (DHET, 2014).

3.2 CONCLUSION: QUESTIONNAIRE ANALYSIS

Once all efforts to maximise respondent participation had been exhausted, it was decided that the final data set had been arrived at. At this point, the responses were then exported to Microsoft Excel using the Google Form’s built-in functionality. Respondents’ names, the date of response, the business sector, and the name of their company (for correlation with the complete survey recipient index), along with their answers to the survey were listed in rows; while columns were headed by the questions posed by the survey. This made navigating through the data relatively easy, and allowed for the aggregation and summary of responses to each question. That is to say, all responses to a particular question (by one of the six business sectors) could be reviewed in one column. Furthermore, sorting of the data by business sectors also made quantitative breakdowns and qualitative comparisons possible.
To begin the data analysis, the objectives of each question were re-examined. These core objectives were set in the initial design of the questionnaire, as described in Section 3.2.1. Thus equipped with and informed by the objective of each question, a qualitative summary of responses to each question was conducted. In other words, the interrogating and lifting of salient points from across the responses. Where appropriate, consensus or disagreement in responses were also noted. If the data lent itself to basic numeric analysis, this was conducted using Excel’s capabilities in this regard. By these methods, both striking and significant results were thus winnowed from the raw responses. The products of this coherent collation and distillation of data are discussed in the next chapter (Chapter 4).
CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

As elucidated in Section 3.2.1, the questionnaire administered, was designed to garner mine closure professionals’ opinions and expertise on certain aspects of mine closure in South Africa. These primarily revolved around: the level of professional experience of South African mine closure practitioners, the types of work environments in which they operate, the current status quo of mining’s environmental indicators and mine closure practices, and lastly recommendations as to best practice in the field of mine closure. This section shall outline and condense the nature of the responses received as per the aforementioned conceptual categories. Concurrently, this collated data on the status quo of mine closure in South Africa shall be interrogated, interpreted and discussed in light of the contemporary literature and legislation on the subject (reviewed in Chapter 2). Due to the open-ended nature of most of the survey questions, the responses have, by in large, been collated and interpreted qualitatively with quantitative details where possible.

4.2 RESPONDENTS’ EXPERIENCE AND WORK ENVIRONMENTS

As mentioned in Section 3.2.3, the criterion for respondents to be included in the survey, was that they have experience of mine closure in South Africa listed on their LinkedIn profiles, or that they were referred by another mine closure professional. Thus this section seeks to summarise and interrogate the nature and level of mine closure experience of the sample population surveyed, namely South African mine closure professionals.

4.2.1 Sectoral Analysis

Based on reviewing LinkedIn profiles of mine closure professionals and feedback from the pilot questionnaire, it was decided to categorise respondents’ mine closure experience as having taken place predominantly in one of six sectors, namely: Academic, Consultancy, Corporate, Governmental, Legal and Mine Site. These sectors have previously been defined and described in Section 3.2.2. As an initial breakdown, Figure 12 depicts the percentage of respondents by each of these sectors.
As represented in Figure 12, the preponderance of respondents, 70%, worked either on a mine site or as consultants to mine site closure (an equal split of 35% each). It is thus evident that there is consideration and appropriation of funds to address mine closure both in-house and for externally hired contractors. If participants from the corporate (11%) and legal sectors (5%) are added to this, it can be seen that 86% of mine closure professionals are employed in the private sector. This can be seen to indicate a lack of mine closure expertise and capacity in the government and research sectors. This fact is supported by many respondents’ commentary regarding the legislative and bureaucratic challenges of achieving legitimate mine closure in South Africa (to be further discussed in Section 4.5.2).

### 4.2.2 Mineral Type Analysis

Respondents were further asked to list the minerals in which they had mine closure experience. Figure 13 represents the percentage of participants who indicated that they had closure experience in each specific mineral. If a respondent had experience in more than one mineral, each individual mineral was counted as an instance of closure experience in that mineral.
As per Figure 13, coal (33%) and gold (18%) make up for just over half of the respondents’ mine closure experience. With the addition of base metals (10%), platinum (9%) and diamonds (8%), almost 80% of the respondents’ experience was covered. Barring base metals, this is in line with the minerals reviewed in the literature (see Section 2.2.8). A variety of ancillary minerals, each accounting for 1% to 3%, constituted the remaining 20%. From this it is clear that South Africa’s major economic minerals (World Bank & IFC, 2002; COMSA, 2011; StatsSA, 2012b) command 80% of the focus of mine closure specialists.

What is particularly interesting, is that in the further breakdown of this data by sector, respondents who were involved in mine closure on site or at a corporate level (a combined 47% of all respondents), had only ever been involved in the limited list of coal, gold, platinum, diamonds, base metals, iron ore and vanadium operations. This can be contrasted to the range of minerals that consultants (34% of all respondents) had experience in, which included all major and ancillary minerals listed in Figure 13 (excluding vanadium). From this it is evident that larger mining houses (which mine the major economic minerals) employ mine closure expertise in-house; while minerals of lesser economic importance, likely comprising smaller operations, employ consultants to assess and manage their mine closure aspects. This again speaks to a challenge which numerous participants cited as having experienced, in that junior miners are less capable of effectively planning for and implementing successful mine closure due to a lack of capacity and commitment. Due to consultants, by their nature, being employed on a more contractual basis, the long term management of mine closure cannot be addressed with the same consistency (and thus efficacy) as an in-house professional may be capable of.
This shall be further expanded on in Section 4.5.2 which encompasses the challenges which participants felt South African mine closure practice is facing.

Of the few participants who work for government (7%), their mine closure experience was only indicated in coal, gold and asbestos operations. This is concerning considering that the government is required to address all types of mine closures from a legislative and compliance standpoint. This can be put in stark perspective in that, in 2005, there were 55 economic minerals produced from 1113 mines in South Africa (DEA, 2010a). Further to this, academic research involvement in mine closure was only shown to extend to coal, gold and base metals. Both these factors and numerous respondents’ comments, point toward the lack of institutional capacity in mine closure compliance monitoring and enforcement as well as the support of long term studies on mine closure impacts and remediation. Legal respondents commented that South African mine closure legislation is not differentiated by mineral; however it was again evident that their experience: limited to coal, platinum and iron ore, abided to only the previously mentioned major economic minerals. That is to say, lesser economic minerals and smaller mining houses are unlikely to have an in-house legal expert on mine closure; this again speaks to the lack of small and junior miners’ capacity to properly address the complex issue of sustainable mine closure which is likely to result in less comprehensive and sustainable mine closure.

### 4.2.3 Mine Closure Cycle Experience

Further to interrogating which professional sector respondents were employed in, and the minerals in which they had closure experience, the question was also put to them as to which ‘phases of’ or ‘projects relating to’ mine closure they had participated in. This question sought to probe the level and breadth of experience of mine closure professionals in South Africa. The following Table 5 was drawn up in summary of the responses to this open-ended question (posed as such, so as to garner and populate a mine closure activity list). As with the closure experience in minerals, if respondents had experience in multiple phases/projects, each instance was counted individually. As an aid to categorising the data, responses were divided into the major stages of the mining cycle, namely: planning, operational and closure, as well as those independent of stage. Responses which indicated blanket experience in ‘all phases’ of closure were documented separately. In reviewing the data, common projects and activities were identified and differentiated as per Table 5.
Table 5: Respondents’ breadth of mine closure experience.

<table>
<thead>
<tr>
<th>EXPERIENCE</th>
<th>Academic</th>
<th>Consultancy</th>
<th>Corporate</th>
<th>Government</th>
<th>Legal</th>
<th>Mine site</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>All phases: Planning, operational, closure, costing &amp; monitoring</td>
<td>1</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>PLANNING STAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline assessments</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Feasibility &amp; conceptual closure planning &amp; design</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Mine closure framework &amp; planning</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Emergency response planning</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>OPERATIONAL STAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational rehabilitation &amp; performance assessment</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Operational closure performance assessment</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Closure studies, trials &amp; assessment of post closure land-use options</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Progressive rehabilitation planning &amp; design &amp; implementation</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>CLOSURE PHASE</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Closure implementation &amp; rehabilitation management</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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<td>3</td>
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<tr>
<td>Post mining monitoring &amp; performance assessment</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Application for closure &amp; government consultation</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Water treatment/reclamation</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>INDEPENDENT OF STAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drafting, updating &amp; auditing detailed closure plans &amp; programs</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Closure liability assessment &amp; costing</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Water prediction/balances, monitoring &amp; management</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Mine closure regulation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Legal matters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Setting closure standards</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Closure risk assessments</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Community engagement &amp; planning for closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>4</td>
<td>40</td>
<td>9</td>
<td>12</td>
<td>3</td>
<td>39</td>
<td>107</td>
</tr>
</tbody>
</table>
In general consideration of Table 5, the predictable responses regarding closure planning, auditing, costing and rehabilitation are evidenced. However, noteworthy is the number of responses regarding water treatment and/or reclamation. This points to the significant research and application of water treatment technologies as a progressively ‘turned-to’ solution for the typically long term water issues associated with mine closure. Noting the relatively high number of responses citing involvement in water management, affirms the priority of the mitigation of water impacts by mining and closure in a water scarce South Africa (Muller et al, 2009; Hanlon, 2010; Wassung, 2010).

As clearly evidenced by Table 5, consultants have the broadest range of experience in differing aspects of mine closure; as well as self-attestedly, the entire gamut of mine closure. Further to this, consultants indicate the most experience in drafting closure plans, conducting baseline assessments, as well as closure costing, all of which require consideration of most all aspects of closure. These points correlate with the finding that consultants also have the broadest experience in differing minerals (Section 4.2.2); again reinforcing the understanding that closure expertise can often be outsourced. This is also likely due to South African legislation specifying that independent experts conduct certain studies such as EIA’s (DEA, 2010b).

As can be expected, respondents working on mines sites are most involved in the operational aspects of closure, while government officials are predominantly involved in closure standards, regulation and monitoring. An interesting relationship between these two sectors can be seen in that it is solely participants from mining sites who stated that they are directly consulting with and applying for closure with government. Respondents from the legal sector are confined to the legal activities regarding closure, but it is of possible importance that none of the other sectors indicated specific legal closure experience (further discussed in Section 4.6.1). Of interest in the academic sector, is the sole occurrence of the preparation of mine closure emergency response plans; this possibly points to a lack of closure emergency planning as a specific consideration in mine closure planning. Lastly, as a sector, corporate experience was evidenced to be of a strategic nature as is consummate with their function.

A concerning aspect evidenced by Table 5 must be commented upon, in that certain crucial activities are represented by a low number of respondents; most conspicuously: the conducting of baseline assessments, closure studies and trials, post-mining monitoring and community engagement. This observation is supported by responses in Section 4.3 regarding the evidenced status quo, which purports that: baseline indicators oft prove to be inadequate, long term trials are little conducted, post-mining monitoring can be simplistic and communities are not adequately involved in an integrated closure process.
In all, Table 5, evidences a broad working practice of mine closure experts in South Africa; and although there areas which appear to be lacking in attention, there are no striking omissions when compared to the considerations of international mine closure literature (Section 2.3.3). Such expertise is even perhaps to be expected in a country such as South Africa where a mature mining and economic sector exists and sustainable development is integrated into national legislation.

4.3 STATUS QUO OF MINING ENVIRONMENTAL INDICATORS IN SOUTH AFRICA

The monitoring and measuring of specified environmental indicators is legally binding due to the manner in which mining licences are administered by the Department of Mineral Resources (DMR). All licences require an EIA and an Environmental Management Plan (EMP) (DME, 2002). Thus to establish the current operational environmental monitoring status quo in South Africa, respondents were asked what baseline and operational environmental indicators are measured at operating and/or closing mining projects they have worked on, as well as to which indicators they have found to be most lacking.

4.3.1 Baseline Environmental Indicators

Most respondents indicated that the EIA process resulted in the production of baseline environmental indicators, especially for new operations. However, there was significant comment passed by most all professional sectors that baseline studies and resultant Environmental Management Plans (EMPs’s) were generally poorly conducted, which gives rise to inadequate baseline indicators. An upshot of this being that closure studies later on are hindered by the lack of a reliable baseline for comparison as well as goal setting purposes. Particular criticism was levelled at the insufficient time, in the permitting process, given to conducting these studies. That is to say, the data collected in these studies is often single-sample rather than longitudinal. This results in poorly understood local environmental systems and consequently weak or vague management plans which are then “paper [and] tick-box exercises”, as numerous respondents put it. Indicators which are measured at this stage are often later revealed to be too few in breadth and detail to provide scientifically adequate and holistically robust post-mining goals to work toward. Thus restoration (and the verifiable measurement thereof) to pre-mining land use, as South African environmental legislation advocates (DME, 2004), is difficult to truly achieve; in part due to these imprecise baseline studies.
Baseline studies and their results, often, are not revisited as mining progresses; and by the time closure is an immanent concern, these studies have become dated in their methodologies and comprehensiveness of content, and thus may no longer even be applicable or useful in directing closure. Most all respondents held views of this nature, but particularly levelled such criticism at older mining sites. This is understandably the case as South African environmental legislation and responsibilities, even twenty years ago, were not as stringent as they are today regarding pre-mining impact assessments (Glazewski & Posnik, 2000). There was the indication that retrospective baseline studies were conducted in some instances, although no detail was given as to what this entailed. The realistic upshot of poor baseline studies was even evinced by a certain expert who responded that: “I have never seen any closure process in which the original baseline data were compared at closure time to the desired end state”; seemingly due to the lack of baseline data integrity. Such views were commonly held; moreover there were no discernible patterns of interest between the six professional sectors which indicated anything but consensus on this point.

An interesting comment was passed by one respondent who maintained that, while baseline indicators are of value in benchmarking against contamination which should be remediated, they provide poor points of reference following mining where fundamental changes have occurred to the physical environment, particularly the geohydrology of the substrate. Thus, despite the best intentions, the post-mining environment will differ in its hydrogeological (and biological) characteristics in comparison to the pre-mining condition (Worral et al, 2009). This is could be viewed as a flaw in current notions of what it means for sustainable mine closure to be achieved; and thus putting the common ideal of ‘rehabilitating to a pre-mining state’ into question. However, a professional from the Department of Minerals Resources (DMR) did comment in the survey that the Department may give allowance for the negotiation of a post-mining condition which differs to the pre-mining condition, provided that the DMR duly interrogates and consents to the proposal. This is corroborated by the Department of Minerals and Energy’s (now DMR) Government Notice R. 527, which in Section 56, Principles for mine closure, subsection (e) states: “[The mine right holder must ensure that] the land is rehabilitated, as far as is practicable, to its natural state, or to a predetermined and agreed standard or land use which conforms to the concept of sustainable development” (DME, 2004).

Based on the responses received, seven ‘basic categories’ of baseline indicators were evident and were subsequently used to classify the indicators supplied by the respondents. These categories mirror conventional environmental indicator classes (DME, 1992; Miranda et al, 2005; IFC, 2007a; GRI, 2013) namely: Land Use, Water, Waste, Air, Geology and Soils, Biodiversity and Social. Here follows, in Table 6, a consolidated list of baseline indicators as provided by respondents.
### Table 6: Consolidated baseline indicators and studies provided by South African mine closure practitioners.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>Water quantity and quality: ground (depth, yields, flow directions, quality) and surface (volumes, quality, drainage patterns)</td>
</tr>
<tr>
<td></td>
<td>Geohydrology</td>
</tr>
<tr>
<td></td>
<td>Sensitive water catchments and water scarcity areas</td>
</tr>
<tr>
<td><strong>Biodiversity</strong></td>
<td>Biodiversity: fauna and flora</td>
</tr>
<tr>
<td></td>
<td>Ecological functioning</td>
</tr>
<tr>
<td></td>
<td>Protected species (red data species)</td>
</tr>
<tr>
<td></td>
<td>Other species assessment standards e.g. MIRAI (Thirion, 2007)</td>
</tr>
<tr>
<td><strong>Air</strong></td>
<td>Air quality (SOx, NOx, respirable particulate matter and fallout dust)</td>
</tr>
<tr>
<td></td>
<td>Climatic data (rainfall, temperature, evaporation, wind speeds and direction)</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Geology &amp; Soils</strong></td>
<td>Soils (types, depth, structure, quantity and distribution)</td>
</tr>
<tr>
<td></td>
<td>Geology (formations, depth, distribution)</td>
</tr>
<tr>
<td></td>
<td>Soil capacity</td>
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<tr>
<td></td>
<td>Vibration</td>
</tr>
<tr>
<td></td>
<td>Topography</td>
</tr>
<tr>
<td><strong>Land use</strong></td>
<td>Land use</td>
</tr>
<tr>
<td></td>
<td>Land capability (potential yield, water retention and infiltration rates, organic composition)</td>
</tr>
<tr>
<td></td>
<td>Nature conservation areas / Sensitive landscapes</td>
</tr>
<tr>
<td></td>
<td>Agricultural and/or forestry potential</td>
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<tr>
<td></td>
<td>Industrial development potential</td>
</tr>
<tr>
<td></td>
<td>Population and planned/unplanned residential densification</td>
</tr>
<tr>
<td><strong>Waste</strong></td>
<td>Waste management</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>Social (demographics, number of households, types of employment)</td>
</tr>
<tr>
<td></td>
<td>Heritage sites (archaeological &amp; culturally important/sensitive areas)</td>
</tr>
<tr>
<td></td>
<td>Visual/Aesthetic</td>
</tr>
</tbody>
</table>
By a large margin, water quality (both underground and surface) was the most cited baseline indicator. This was followed by biodiversity (faunal and floral), air quality, soil quality and land use respectively. At the very least, ten separate respondents named each of the aforesaid indicators. Thus, excluding waste (a more atypical baseline indicator, though waste management options could be defined at this early stage), and social indicators, all of the aforementioned ‘basic classes’ are well represented. That social indicators are poorly represented is likely significant (based on other comments received by participants, see Section 4.4.2), although again this study has focused on environmental indicators.

These class defining indicators were followed by noise, land capacity and geology; each with at least five instances. Here more nuance is seen in the indicators and their function. Specifically, a lack of land capability studies would jeopardise well-defined closure planning and final land use goals. One respondent also specifically commented that very little geochemistry characterisation is conducted. This again creates difficulties in closure planning as the characterisation of potential AMD should be done initially so as to design discard dumps and mine water flows with a view to the most sustainable closure (Expert Team of the Inter-Ministerial Committee, 2010). The remaining indicators specified were in the minority. Specifically mentioned by a respondent was that visual baseline assessments to guide the contouring and closure of tailings facilities or waste dumps are neglected. Soil capacity and ecological relations, both being more detailed and complex studies than soil characterisation and biodiversity assessments, are also rarely conducted – which may be due to a lack of expertise and/or funding. It also seems that studies which deeply interrogate future land use potentials are uncommon.

Thus it can be seen that although baseline studies are currently integrated into new mine developments in South Africa, they may not encompass adequate detail and recommendations with an embedded view to from the outset directing actual mine design toward sustainable closure. Moreover, with the first fairly comprehensive environmental requirements only being issued by the DME in 1992 (DME, 1992), old mines tend to lack baseline indicators altogether and closure must be aimed for without a holistic understanding of the pre-mining environment. This presents difficulties in sustainably reintegrating the mined landscape into the surrounding environment at closure.

4.3.2 Current Operational Environmental Indicators

The monitoring and measuring of specified environmental indicators is legally binding as per a mine’s approved mining licence administered by the DMR. Concomitant to this licence is a requisite EIA (Environmental Impact Assessment) and consequent EMPR (Environmental Management Programme) (DME, 2002). Thus if, as described in the forgoing Section 4.3.1, the baseline EIA’s informing the permitting process and consequent environmental monitoring
requirements are weak, then operational mines too shall have weak environmental indicators which do not adequately direct closure planning. That is unless, as is often the case with better funded larger mining houses, corporate standards and funding bodies prescribe environmental monitoring which exceed the baseline assessments upon which an EMPR is drafted (IFC, 2012; ICMM, 2014b). This again highlights that diligent mine closure planning is by necessity integrated into each phase of the mine life cycle, expressly at the feasibility and planning phases. Such considerations thus may inform the design and management of activities towards ultimate closure, with comprehensive and directed operational phase environmental monitoring iteratively supporting closure-vision decision making and actions.

Accordingly, to establish the current operational environmental monitoring status quo in South Africa, respondents were asked what indicators are measured at operating and/or closing mining projects they have worked on, as well as to which indicators they have found to be most lacking.

### 4.3.2.1 Specific Operational Indicators

As with baseline indicators, water monitoring, both surface and underground, was stated to be the most frequently available environmental variable measured on mine sites. This was supported by comments that, due to Section 21 ‘water uses’ (DWAF, 1998) being regulated and licenced separately by the Department of Water Affairs (DWA), such water monitoring data is more readily available. Water monitoring tended to be divided into quantity and quality aspects. Some respondents commented that water quality monitoring was conducted according to Global Reporting Initiative (GRI) guidelines. The GRI’s Mining and Metals Sector Supplement (GRI, 2013: 31) suggests: “The specific choice of quality parameters will vary depending on the organization’s products/services/operations. The selection of parameters should be consistent with those used in the organization’s sector. Clean water refers to water that meets national regulations for freshwater quality when leaving the boundaries of the reporting organization.” Thus the South African Water Quality Guidelines issued by the DWA should inform water quality monitoring at mine sites (DWAF, 1996).

Basic biodiversity monitoring was also frequently conducted during the operational phase. Specifically mentioned were: the relative abundance of species, plant basal cover, invertebrates status, presence of red data or protected species and alien invasive species monitoring. Again this ties into South African legislation; namely Chapter 3, Biodiversity Planning and Monitoring, of the National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) (DEAT, 2004a). Basic air quality monitoring is also broadly conducted. Primarily for fallout (nuisance) dust, and nominally, respirable dust monitoring, with merely a few instances of PM10 monitoring, and just one instance of PM2.5 monitoring (DEAT, 2004b).
Following on this, soil depth and fertility were cited as recorded parameters followed by land capability. This set of indicators abides by the ‘basic classes’ arrived at in the preceding section on baseline indicators (Section 4.3.1). During the operational phase, additional indicators respondents stated were monitored (albeit at lower frequencies than the ‘basic indicator classes’), were: energy usage, surface subsidence, waste generation, progressive rehabilitation, noise, blast and vibration and EMS compliance. Closure planning (backlog liability), greenhouse gas emissions, complaints, tailing seepage monitoring, erosion, stocking rates and social sustainability indicators were also cited, but only by a single respondent a piece. Again (as in Section 4.3.1), these responses indicate that it is the more detailed and complex environmental indicators which lack attention in South Africa; nonetheless, it is expressly these more complex studies which support sustainable mine closure (see Section 4.4.2).

The following section shall discuss particular inadequacies perceived by respondents in the measuring of these environmental indicators during the operation phase which would inform ultimate mine closure.

4.3.2.2 Operational Indicators Found to be Lacking

Respondents detailed which environmental indicators they found most lacking on operating and closing mines. Air quality parameters, aside from dust fallout, were said not to be monitored, namely NO\textsubscript{x}, SO\textsubscript{x}, CO\textsubscript{2} and even in numerous instances a lack of respirable dust monitoring (PM10 and PM 2.5). Responses also indicated that even within the ‘basic indicator classes’ (Section 4.3.1) there were other inadequacies or gaps in monitoring, specifically regarding more complex ecological studies and detailed soil monitoring (depths, organic composition, expected agricultural yield, carrying capacity, stability requirements, erodibility, water infiltration characteristics). Consequently there would be a poor understanding of land capability, which in turn impacts negatively on the capacity to define and target a final land use (see Section 4.4.2). Concerns of a similar nature were voiced by participants in whose experience complex environmental pathways/interactions were poorly studied and understood on mine sites. Climate change and greenhouse gas emissions were cited a number of times as environmental aspects which likewise were little considered or measured. Social indicators, a sense of place and visual (aesthetic) considerations were also named as being insufficient. A significant number of participants made direct comment that environmental indicators data is frequently of a poor quality. This indicator data was moreover criticised for being inconsistent and of a variable standard. It was added that weak data management is a factor in these instances.
It was strongly commented upon by numerous experts that cumulative impacts in particular were neither identified nor monitored across regions and mining sites. It was elucidated that each mine is regarded as a single entity for licencing purposes, but in reality their environmental impacts are cumulative. This is regarded as a major shortcoming of the current legislative approach with negative ‘real world’ implications for sustainable closure. Section 24R(5) of NEMA does however provide that the Minister of Environmental Affairs may, “by notice in the Gazette, publish strategies in order to facilitate mine closure where mines are interconnected, have an integrated impact or pose a cumulative impact” (DEAT, 1998). Nevertheless, to date no such strategy has been published (Humby, 2013).

The lack of detailed specialist monitoring is likely due to high equipment and maintenance costs and the level of expertise required to accurately operate such monitoring devices. Following from this, the more detailed and complex environmental studies are also likely hindered by cost implications. No government notices to effect strategies dealing with cumulative impacts appear to have been published. This affirms the alleged status quo of omitting attention to indicators of cumulative impact in mine closure. Voluntary studies of such complex nature are likely stymied by budgetary constraints and a lack of top management buy-in. These inadequacies may also be attributed to the relative difficulty and depth of research required to generate meaningful indicators of complex environmental aspects (and interactions), as well as consistently measuring them over long periods of time. With data either missing, or being of poor quality and detail, there is consequently little scientific value in leveraging such environmental data in directing closure plans.

4.3.3 Environmental Indicators Beyond the Mine Site Boundary

As environmental impacts, through environmental transport pathways, extend beyond the legislated mine lease area, mine operators have a responsibility to monitor environmental indicators outside their boundaries (DME, 2004). Thus participants were asked if such monitoring is in fact practiced and which indicators are regularly measured. The majority of respondents stated that basic environmental indicators were measured beyond the mine lease boundary; usually between one and five kilometres. These were primarily water (ground and surface) and dust (fallout), and to a lesser extent, biodiversity and blast and vibration. Water was measured as far away as 100km, and typically both up and down stream of operations; while dust and blast impact monitoring focused on nearby communities. Biodiversity may be monitored within a 10 to 15km buffer zone dependant on the species. Waste transported and disposed offsite (particularly hazardous waste) was also measured. However these self-same respondents also indicated that the preponderance of monitoring still takes place within the mine boundary. A significant (though lesser) number of participants stated that no monitoring whatsoever is conducted outside the mine limit, unless a public complaint prompted an investigation. Evident in these responses is that mining operations do not focus strongly on
cumulative environmental impacts (as corroborated by responses in Section 4.3.2.2). This shall present as a problem upon the advent of closure, as little data shall be available on the extent and severity of the mine’s off-site environmental impacts. Consequently, differentiating between background environmental levels and a mine’s off-site impacts can prove difficult; with the repercussion that managing and appropriately mitigating such undefined ‘extended’ impacts becomes near impossible.

4.3.4 Do Environmental Indicators Relate to Final Land Use?

To establish if the ‘loop is closed’, that is to say if indicators are monitored to aid in final land use determination, participants were asked if in fact indicators do in fact relate to the planned final land use. By in large, consultant and government participants stated that they did not find environmental indicators to be explicitly related to final land use. However they did believe that this should be the case, as clearly demonstrated by one participant’s response: “Environmental indicators must relate to intentional decisions around land use”. International literature around this subject supports this view (Martínez & Gómez, 2002; EC, 2004; Azapagic, 2004; Villas-Bôas, 2005; Worral, 2009).

In response to the survey, it was commented that in South Africa the assessment of a broad spectrum of land use options to determine the most optimal land use/s is typically lacking. Moreover it was pointed out that if certain indicators are neglected, when the final land use is achieved, underlying and undetected impacts may surface with time. It was also stated that environmental monitoring can simply be driven by legal compliance rather than the need for proactive understanding of environmental impacts and closure considerations. This is a weak form of management by compliance alone. However, corporate and mine site respondents in particular indicated to the contrary: that the management of mine closure (as part of a broader risk management process) related environmental indicators and final land use. Examples were given, such as agricultural land capability, water quality and quantity, topography, biodiversity assessments and grassland management relating to the planned final land use. Again directly quoting one respondent: “The results of the monitoring programmes, for example, will drive the rehabilitation plan and focus the money available therefore. Monitoring results further show whether or not rehabilitation is successful and whether the land can be released for the final land use it is intended for.”

Nonetheless, it was said that conceptual models which related source, pathway and receptor (Suter II, 1999) tended not to be defined and thus precipitated poor management of environmental impacts and closure. The difference between land capability and end land use was also highlighted; as ultimately due to a lack of integrated planning, the two may not actively be aligned and sustainable closure consequently undermined. Also particular comment was passed on the necessity of integrating community sustainability into closure, such that the
final land use remains environmentally sustainable (echoed by Limpitlaw & Hoadly, 2006 and Hoadley & Limpitlaw, 2008). Thus it can be seen that final land use can be a nebulous concept which is often vaguely aimed for during the operating phase rather than explicitly and specifically leveraging environmental indicators to refine and define an end land use.

4.3.5 Ideal Environmental Indicators

Having interrogated and examined the status quo of baseline and current operational environmental indicators in South Africa, participants were asked to detail what they considered ideal environmental indicators required to support sustainable mine closure. The majority of responses cited water as being the most important environmental indicator needing to be measured throughout the life of mine, as is evidenced in the quote: “A clear focus on water: in almost all cases it is the long term water management issues that predominate in the post-closure environmental impact, yet so many assessments fail to cover it adequately.”

Both surface and underground water quality and flows were considered very important. This extended to water balance models, as well as water quality and quantity (excess make) predictions. Other specifics included: expected clean and dirty water make and/or runoff, water ecosystem health and ground water levels. It was advised that monitoring boreholes should be positioned along flow paths between source and receptor, and potential decant points monitored while slopes should be free-draining away from final voids to minimise water make (infiltration and potential pollution). The next most frequently suggested monitoring, was that of soils and land capability. This was related to defining and measuring progress towards a final sustainable land use. Stable reshaped topography and adequate rehabilitated topsoil depth were deemed imperative to establishing a stabilising basal cover and thus minimising erosion. Soil erodability studies (particle size distribution) were also recommended. Vegetation monitoring, with the end goal of successful surface rehabilitation, was cited by numerous participants; moreover that successfully re-established indigenous vegetation should support sustainable fauna. Ultimately the monitoring of biodiversity establishment and ecosystem services and/or landscape function analysis should indicate the success and sustainability of this rehabilitation. The ‘loop’ may be ‘closed’ in this respect by gearing the rehabilitation and its success toward the agreed final land use and the capacity to sustain the activities for which it shall be used. Absolom and Limpitlaw (2005) for example provide a South African case study in which the importance of, and challenges relating to, practically realising this linkage between final land use and land capability are discussed.

Air quality and dust monitoring were also deemed necessary by numerous respondents. However little detail other than specifying the monitoring of particulate matter (PM10 and PM2.5) and $${\text{SO}}_x$$, $${\text{NO}}_x$$ was provided. Visual impacts, noise, sense of place, radioactive sources (gold mines) and wetland specific monitoring were mentioned a limited number of times. Mine
residue deposits were also noted as requiring monitoring; particularly regarding contaminated runoff, seepage, stability and fugitive dust as well as the spontaneous combustion of coal discards in particular. Certain participants provided feedback which included social indicator considerations, and although these are beyond the formal scope of this dissertation, they bear relevance regarding sustainable closure as social and environmental aspects are interrelated. This is supported by the following direct quote: “Ideally, those [indicators which require monitoring are those] relating to sustainable livelihoods and maintenance of dynamic ecosystem functioning. From a social perspective, this would include agricultural potential, access to clean water, access to sustainable markets, technology transfer opportunities. These may not seem like environmental indicators, but measuring and monitoring these will contribute to sustainable environments after closure. From the perspective of maintaining dynamic ecological equilibrium, baseline data need to be collected over at least 2 years, habitat functionality tracked, limiting and enabling (natural) factors identified and monitored.”

Numerous other respondents also spoke directly to the monitoring of ecosystem functioning as an imperative in achieving sustainable mine closure. One respondent specifically detailed it as such: “Fundamentally, indicators need to reflect system functionality and the return of functionality into rehabilitated systems. Consequently, while it is important to measure key environmental components it is most important to interpret data from a functional perspective and to collect data that reflects functional drivers within systems. Thus, as an example to measure reproductive success (vegetative and sexual reproduction) within plant communities in addition to understanding species abundance. Similarly, indicators of soil nutrient cycling and soil microbial vigour rather than just soil chemistry.”

Thus environmental indicators should be comprehensive, holistic and site specific. If rigorous baseline studies are conducted, the findings can be fed into a legally approved environmental management plan which shall direct operational monitoring and inform closure planning. The financial liability of closure can consequently and concurrently be tracked and closure provisioning adjusted accordingly. The same applies to monitoring and directing the social outcomes of closure. All this must also be done within a regional context for mine closure to truly approach sustainability. Were closure to be conducted thus, neither the state nor the mine operator would view the land as a liability to be rid of (Seccombe, 2014).
4.4 MINE CLOSURE AND CLOSURE PLANNING

4.4.1 The Existence of Mine Closure Plans and Closure Reporting

Considering that much of the literature review points toward the necessity of robust and detailed mine closure planning (corroborated by this study’s respondents), participants were asked if, in their experience, mine closure plans were in place in South Africa; as well as if they were reported upon. Opinions were divided on this subject. Numerous participants said that mines only planned for “short term goals”; while the majority indicated that some form of mine closure plan was in place on the mines they had worked upon. The general views on the latter were neatly summed up by one participant: “Approximately 70-80% have some sort of closure planning in place, although less than 50% is sufficient and only 10-20% is comprehensive.”

Due to its being legislated (DME, 2002) and often a corporate requirement (ICMM, 2014b), most all mines were at the very least seen to be currently developing closure plans according to the survey. However of particular concern, and which was stated more than once, is that the contents of these plans are often not realistically or practicably achievable. Thus ultimately, approved closure plans may fall short in reality. Comment was also passed that often rehabilitation plans are incorrectly deemed as closure plans. The updating of closure plans was either regular (often annual) or ad-hoc and based on material mining project changes. As the mine aged, it was indicated that closure plans should become more detailed and comprehensive due to an accrual of monitoring data and studies, as well as the nearing of the end of the life of the mine. Only one participant indicated that sudden and unforeseen closure was an important facet of closure planning.

Corporate and mine site respondents indicated that mine closure performance did roll up to corporate and public reporting levels, while government respondents replied that mine closure measures do not roll up to national reporting on sustainable development. Sorensen (2012) found that while sustainability reporting is conducted by major mining companies in South Africa, it does not comprehensively cover all aspects of sustainability. Thus it again is confirmed by this survey that although mine closure plans do exist, they generally appear to be of an inadequate quality (both structurally and in terms of content) to truly direct mines toward sustainable closure, and thus a poor standard of mine closure continues to prevail in South Africa.
4.4.2 Imperative Investigations for Mine Closure

Participants were asked what they considered to be imperative environmental studies to be undertaken so as to best support sustainable mine closure. The responses received were similar to those in Section 4.3.5 regarding ideal environmental indicators. Consistently, detailed studies on both surface and ground water were advocated. In particular: long term water balance (quantity), and geohydrological (quality) models and predictions. Associated with this were geotechnical and geochemical models and predictions of surface waste dumps’ physical and chemical evolution. The Department of Water Affairs and Forestry’s *Best Practice Guidelines for Water Resource Protection in the South African Mining Industry* series was advocated in this respect (DWAF, 2008). Such studies should feed into integrated mine water management plans which would consequently inform closure planning (ICMM, 2006). Again soil investigations in the broader context of land capability studies were also deemed by survey participants as being very important in guiding land use determination. Ancillary to this, erosion modelling/slope stability analysis and soil nutrient function and microbial contribution were advocated. The sustainability of revegetation on rehabilitated land is also deemed an important long term study which should be undertaken; and this is complemented by biodiversity investigations including alien invasive species control. In adopting a holist approach, ecosystem services should be determined and valued to internalise closure costs; as highlighted by one participant: “*Fundamentally, studies to inform closure planning need to focus on systems functionality.*”

Social studies were not focused upon, but numerous responses indicated that community engagement must be aligned with environmental closure investigations which guide the final land use determination. Ultimately, it was stated that a sustainable land use can be approached by determining and linking social and environmental needs which reintegrate mining landscapes into the regional landscape. Other important desktop studies put forward included: gap analyses which determined shortcomings in the closure planning, and led to specific and detailed studies and actions which addressed these gaps; corporate reputational risk analysis; closure funding liability assessments; waste dump reuse investigations; post-closure dust generation; environmental history investigation; climate change risks; post-closure monitoring; sudden and unforeseen closure planning; trade-off investigations and biodiversity offset opportunities. Thus, in conjunction with Section 4.3.5, the complexity of environmental studies and indicators which would inform robust and sustainable closure plans is seen.
4.4.3 Is There Successful Mine Closure in South Africa?

Participants were asked if they were aware of any successful mine closures in South Africa. That is to say: have residual risks been mitigated, a sustainable land use established and a closure certificate issued by the state? The predominant response in this respect is that no mines had achieved legal closure in South Africa. The consensus was that while sustainable post-closure land uses have been achieved in certain instances, closure certification still remains essentially unobtainable. This may be due to the fact that although a land use may be sustainable, for it to remain so, there are environmental risks which still need to be managed. Latent and residual environmental impacts persist in almost all cases, and the state is unwilling to accept any such liability. Moreover achieving a sustainable post-closure land use is not the norm. A respondent even went as far as to say that: “No mines have received closure certificates, so they either become derelict and ownerless in SA, or they are foisted off onto BEE partners who often do not do an adequate due diligence to evaluate the embedded liability they carry.” This is supported by a case study of the Blyvooruitzicht gold mine presented by Ms. T. Humby at the 9th International Mine Closure Conference (Seccombe, 2014).

Primarily post-closure water issues were cited as being the largest barrier to achieving sustainable closure. For example, AMD may persist for many years after closure (Johnson & Hallberg, 2005; Expert Team of the Inter-Ministerial Committee, 2010). It was commented that sand, limestone and aggregates mining sites were much easier to close than gold, coal and platinum mines due to the fact that long term changes in environmental chemistry do not accompany mining. A small number of respondents did indicate that there have been closure certificates successfully issued in South Africa; however, of these, site specific maintenance issues still persisted. This essentially confirms that the concept of ‘no residual impacts’ is unachievable and that a “dead-lock” exists between mining companies and the South African government in this respect. The upshot of this ‘unattainability of closure’ in South Africa is that: “Smaller mines may consider liquidating themselves, with the abandoned mines then reverting to state responsibility. The bigger mines sometimes find it easier, and cheaper, to "moth-ball" a mine rather than going for expensive closures.”

Ideally a comprehensive maintenance and monitoring program is required post-closure to quantify remaining residual environmental impacts. This however should be the culmination of a proactive, progressive and detailed closure plan which was initiated during the feasibility phase. Impacts should be identified and avoided or mitigated throughout, and responsibility appropriately allocated. The financial responsibilities must be borne by the mining company on the basis of the ‘polluter pays principle’ which is embedded in section 41 of the MPRDA (DME, 2002).
4.5 DISCUSSION OF CHALLENGES AND SUCCESSES OF MINE CLOSURE IN SOUTH AFRICA

Respondents were asked to detail specific successes and challenges that they had encountered in their professional mine closure work. This interrogation sought to ascertain both best practice and areas of concern in South African mine closure.

4.5.1 Successes

The overriding response received stated that top management buy-in was the prime driver behind successes in mine closure. The concept of “mining for closure” ensures the integration of mine closure objectives into operational mine planning. By continually demonstrating the cost benefits of proactive closure planning, concurrent rehabilitation, as well successful ‘on-the-ground’ research trials, top management’s commitment to mine closure can be strengthened according to survey responses. Furthermore, trade-off considerations should factor in the short, medium and long term risks and costs of mine management (and design) decisions. Again respondents spoke to the imperative of continuous rehabilitation and dumping strategies which obviated double material handling at later stages. From a corporate respondent standpoint, setting and implementing group wide mine closure standards, which include a strict supervision of closure liabilities, is a means to direct and audit operations. Moreover, quantitative surveys of all areas and infrastructure are deemed necessary to best assess the quanta of rehabilitation to be integrated into a detailed mine closure plan; these must also be regularly updated and closure costing and funding managed accordingly. With reference to the previous Section (4.3.1) on baseline indicator data, a participant is quoted as follows: “Successes are in instances where sufficient baseline information is available and pro-active planning and client engagement exists in terms of closure planning.”

Closure training and awareness was also seen to be a success factor when encouraged beyond top management. The creation and support of a dedicated closure team was also said to be a significant factor in success. This included the establishment of a steering committee and the participation of production staff. Other specific successes which were cited included: topsoil recovery prior to mining, endangered plant recovery, alien species control, diligent topsoil management and placement, the planting of indigenous vegetation on rehab areas, shaping to ensure free-draining topography, the sustainable rehabilitation of waste dumps and particular successes with artificial wetlands. The implementation of such best practices is evident in the response: “The successes largely relate to the application of cutting-edge technology in addressing the residual impacts, including water treatment and rehabilitation practices.”
A specific South African success in this respect is the development of the eMalahleni Water Treatment as a joint venture between mining houses, with local government receiving the treated (to potable standards) mine water (Hobbes et al, 2008). Thus there are successes in the cooperation between certain mine projects and government. As another respondent put it: “It is difficult to judge success. Mining will always result in change in the landscape and in biological systems which re-establish in a changed environment. That said, there are some great examples in the South African coalfield where a return to system functionality is evident 20 years after cessation of mining. Many of the success stories relate specifically to small operations where the footprint of impact was contained.”

Nevertheless there is the potential for other innovative strategies in addressing mine closure beyond the legislative concept of a closure certificate. This is exemplified in a respondent’s quote: “There are too few cases of mine relinquishment to establish the overall success of mine closure. Rather the success ofmine closure planning can be judged more by cost savings […] of progressive rehabilitation [and the] recognition that some mining waste is another company’s resource.”

Thus successes can be seen to be driven by top management buy-in to the priority of mine closure, which supports diligent scientific monitoring and research, which in turn informs detailed closure planning which must be executed as continuous rehabilitation and/or innovative land use projects, all while ensuring stakeholder participation for long term sustainable closure. See recommendations in Section 5.3.

4.5.2 Challenges

The prime challenge facing sustainable mine closure cited by most respondents was the inadequate funding and cash flow management of closure. The consequence being that long term remediation measures could not be continued due to budget constraints. The literature concurs with this situation, for example Picarelli et al (2014). This situation is particularly the case at the end of life of mine when cash flow declines, while deferred closure costs compound. Quoting a survey respondent: “Key failure lies in mine closure generally being pushed out towards the end of the life of mine when money gets tight.”

Closure costings exercises themselves were said to be inaccurate and unrealistic, thereby negating aiming for the closure option with the best social, economic and environmental benefits. It was further stated that mine closure planning was also often poorly conducted and/or complied with. Early and long term commitment to, and iterative informed updating of, mine closure plans was said to be weak. Moreover changes in legislation (the closure ‘goalposts’), as well as uncommitted senior mine management, seriously impair long term closure planning. It was also commented that government has failed to prosecute non-
compliant mines regarding closure issues, thereby undermining the strength of the legislation and setting a weak example. Final water quality is also a major challenge facing mine closure in South Africa (Expert Team of the Inter-Ministerial Committee, 2010; McCarthy, 2011). Specialists commented that it is particularly difficult to predict the final water make and quality of a mining site (especially if data availability and quality is an issue). This uncertainty makes the adequate apportionment of costs to the sustainable management of post-closure water issues problematic. This was corroborated by the issue raised, regarding complex geohydrological issues, which are usually poorly investigated and understood. This matter of determining residual environmental impacts extends beyond water quality issues to other environmental aspects such as soil capacity, erosion and wind-blown dust from dumps. Another significant challenge which professionals put forward was that of sustainable rehabilitation. Poorly executed topsoil management, sloping, double handling and material placement were contingent issues. The difficulty of establishing sustainable vegetation cover in instances of poor soil quality was also named.

The interactions between stakeholders was cited as a recurrent challenge. Respondents stated that communities are not adequately cohesive such as to make informed decisions, their expectations may be impracticable and communication barriers exist. Moreover, mines do not conduct effective closure consultation throughout the mine life cycle for all stakeholders to buy into a final land use. It was also said that mines are often reluctant to share monitoring data with communities. Government departments are found to be under-resourced, to both timeously and rigorously, deal with final land use deliberations and closure applications. Limpitlaw’s (2004a) research highlighting the key challenges facing the South African minerals industry concurs with these findings. Small mines which do not have the resources to monitor and direct operations toward sustainable closure are also viewed by respondents as a significant problem. Other specific issues which were cited included: a lack of post-closure environmental monitoring, procurement issues in remote mine locations, rainfall (in conjunction with excess water make) causing rehabilitation and reshaping to be very difficult, illegal mining and theft of monitoring infrastructure, cumulative impacts of numerous mines, land use planning, demonstrating final land use and the lack of baseline data, poor monitoring data, studies and long term trials as previously mentioned in Section 4.3.2.2.

The implications of poor planning and budget limitations are that the practical aspects of mine closure (such as reshaping and water treatment) cannot be executed such that mitigation of legacy environmental impacts is dealt with and sustainable closure achieved. As with all planning, if not specific and detailed enough, the end goal will not be achievable. To quote two respondents: “Closure costs can be reduced by paying more upfront to design [and plan] better infrastructure that will close easier and cheaper.” And, “Water quality is always an issue. This is still the biggest challenge for any mine in any phase of operation or closure.”
For these reasons, a move away from active, toward passive water treatment is also seen as a sustainable solution. With poor studies, planning and closure budgeting, water related impacts are unlikely to be adequately comprehended and sustainably mitigated at the end of life of mine. This is especially problematic with water management/treatment being a prime closure cost according to a respondent. Furthermore, it was stated that issues such as poor topsoil management and severe erosion lead to long term closure issues which are not easily rectified as soil is essentially a non-renewable resource.

Aside from there being numerous government departments liable to be involved in environmental closure (DMR, DWA and DEA (Department of Environmental Affairs) for example), as well as too few successful legal closure applications to provide as an exemplar, these particular challenges are best summed up by a quote: “Achieving sustainable closure requires a supportive, stable and mature administrative regime in which a closure proponent can find solutions.”

Final closure approval from authorities is essentially viewed as a practical impossibility, as any residual impacts would become the responsibility of the state; and hence government is extremely unwilling to issue closure certificates. This is particularly problematic, as explained by two participants: “The requirement to reduce mitigated risk to zero is unattainable, and since it cannot be achieved, no mines are getting closure permits. This means that the best possible practices are being rejected, and since undertaking best practice brings no reward, mines are not bothering to do their best.” And, “No mines have been legally closed in South Africa since 1994 as NUM [National Union of Mineworkers] will not allow it (loss of jobs for union members). It is a political impossibility.” The participation of all stakeholders in mine closure planning is also not collaborative enough. In short, these issues speak to a broader inadequacy in strategic planning, technical capacity and a cooperative and regional approach all underpinned by sustainability principles.

Lastly, the interactions between stakeholders involved in directing mine closure were also slated. Corporate and mine site participants tended to criticise government departments’ lack of in-house skills, as well as the efficacy and synergy of cooperative governance. The latter criticism was in a number of instances specifically levelled at inexpert cooperative decision making between the Department of Mineral Resources (DMR) and the Department of Water Affairs (DWA). These two departments are responsible for their own core but interrelated eponymous licencing mandates; with both being required to sign off on final mine closure. Government on the other hand criticised junior miners for not having the money or expertise to adequately and iteratively prepare for sustainable closure. This extended to inadequate closure funding being a problem in general; even to the point that larger mine companies ostensibly sell off mine sites to avoid immanent closure liability (Seccombe, 2014). Nevertheless, larger mining companies often are bound by their parent company’s policy to abide by international standards of certification (eg. ISO 14001 and GRI reporting) and as such
are more likely to have better monitoring and closure plans in place (ICMM, 2014b). However, consultants commented that consolidated and directed closure plans over the substantial life of mine of larger mining houses’ concessions could be piecemeal, with disconnected studies being conducted by different experts over time. That is to say, the term-based nature of contract work was pointed out to weaken the implementation and follow through of consultants’ closure investigations; this being due to mine management not necessarily implementing or integrating a study’s findings. A correlating lack of long term trials was also regarded as a major shortcoming by experts, as such research during the operational phase of the mine could strongly inform sustainable mine closure.

4.6 AWARENESS AND OPINIONS OF SOUTH AFRICAN MINE CLOSURE LEGISLATION

Mine closure is a legislated imperative in South Africa (DME, 2002) (see Section 2.6). Hence, to more completely determine the gap between policy (legislation) and practice, it was deemed necessary to interrogate the participants’ level of awareness of South African mine closure legislation, as well as to garner their expert opinions thereof. Moreover, an indication of the appropriate legal knowledge of mine closure experts, in part, validates their capacity as experts in the field.

4.6.1 Awareness of South African Mine Closure Legislation

At the time of questionnaire development, the four prime sections of South African legislation governing mine closure were listed in a check-box manner, and survey participants were requested to check (mark) those pieces of legislation with which they were familiar, namely:

Full excerpts of these sections of legislation are provided in Appendix B.

It was found that by sector, academics were least familiar with the above listed legislation, while those in the legal profession and government knew the most. It can be construed that it is less imperative for academics to be well versed in closure legislation; however research trials by such academics should be cognisant of the legislative framework. That the legal professionals knew most all applicable legislation is to be expected, however it is encouraging that government employees involved in mine closure were similarly well versed therein. Corporate respondents were also well aware (though with more gaps than legal and governmental sectors) of said legislation, which is consummate to their role of corporate oversight and strategy and policy formulation. Following the corporate sector, lay the consultant and mine site categories respectively. In these cases, approximately 30% of respondents were unaware of each piece of legislation listed above. This is concerning as consultants may be proposing mine closure solutions without fully apprehending closure legislation. Likewise mine site employees may not be developing plans or implementing decisions in full alignment with applicable legislation. This said, it must be accounted for, that a couple of respondents had previous closure experience in South Africa, but now worked abroad, and had not remained abreast of legislative developments. Additionally, there were a few respondents who conducted specialist aspects of mine closure studies (e.g. geohydrological modelling) and consequently were less aware of closure legislation. Nevertheless, for the tenants of sustainability which are embedded in South African mine closure legislation to be successfully effected, considerable knowledge of and alignment with, said legislation should be encouraged in the professional field. Across the four prime pieces of closure legislation listed above, it is notable that there existed variation in the overall familiarity with each section. Table 7 below indicates the overall awareness of respondents’ of South African closure legislation (numbered as per bullet points above).

<table>
<thead>
<tr>
<th>Number</th>
<th>Legislation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NEMA</td>
<td>Yes (75%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No (25%)</td>
</tr>
<tr>
<td>2.</td>
<td>MPRDA</td>
<td>Yes (75%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No (25%)</td>
</tr>
<tr>
<td>3.</td>
<td>NWA</td>
<td>Yes (71%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No (29%)</td>
</tr>
<tr>
<td>4.</td>
<td>GN R.527</td>
<td>Yes (66%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No (34%)</td>
</tr>
</tbody>
</table>

Most respondents (75%) were acquainted with the applicable closure aspects of The National Environmental Management Act (DEAT, 1998) and Minerals and Petroleum Resources Development Act (DME, 2002). However this dropped to 71% and 66% with the National
Water Act (DWAF, 1998) and Government Notice R. 527 respectively (DME, 2004). This is troubling as, in the first instance, as per S43 of the MPRDA, the Department of Water Affairs (DWA) is required to sign off on mine closure. Thus, without the cognisance that the DWA is also required to sign off on mine closure, aspects and specific considerations which fall under their remit may be neglected by closure practitioners. In the second instance, and perhaps more concerning, is the general lack of awareness of GN R. 527 amongst responding mine closure experts. GN R. 527 is known as the Mineral and Petroleum Resources Development Regulations. The drafting of these regulations is contemplated in S107(1) of the MPRDA, and may include inter alia regulations regarding: the management of environmental impacts of a mine site, monitoring and auditing, rehabilitation, mine closure and financial provision. Of particular significance to this study is that GN R. 527 prescribes ‘Principles of Mine Closure’ under Section 56 (DME, 2002; DME, 2004) (see Section 2.6.2. of this dissertation). Thus a lack of awareness by experts in the field, of these explicitly legislated closure principles, may undermine the efficacy of realising sustainable mine closure.

4.6.2 Experts’ Opinions on South African Mine Closure Legislation

The biggest criticism levelled at South African mining and mine closure legislation by survey participants was its instability; as well as the consequent near practical impossibility of obtaining a mine closure certificate from government. Humby (2014) provides details of the history of this legislative instability in her research. Thus, without a mature, stable legislative milieu, and with the ‘goalposts’ repeatedly being changed, mining houses cannot reasonably be expected to aim for a state of closure which will be approved by government. This problem is exacerbated by the extended time frames upon which most mines operate, with closure decisions consequently having long term implications. Stable mining and closure legislation would permit the formulation and implementation of sound closure strategy. As a respondent neatly put it: “Responsible mining companies do strive to give effect to the principles contained in the legislation identified but it is difficult to determine success [in light of regulatory instability].”

Nevertheless, the majority of consultants and mine operations personnel stated that the legislation in the above Section 4.6.1, was in fact considered and incorporated into mine closure plans. There were comments from other participants however, that mines in fact failed to meet their own EMP commitments. An EMP, with associated closure commitments, as well as closure plans themselves, are legally binding documents which mines have to produce and abide by (DME, 2002). Again, as with closure planning, numerous respondents said that it was smaller mines in particular who fell short of adequately considering and implementing closure legislation. Certain respondents, from larger mining houses, stated that their closure process is more onerous than those required by South African legislation. That is to say South African legal requirements are included, but this is gone above and beyond and includes international
best practice. Understandably larger mining houses are more likely to have the capacity for the research and development of such a comprehensive closure strategy.

Bearing in mind that the number of respondents from government was low, it was still problematic that most of these civil servants responded that they did not audit mines according to closure legislation. Furthermore, such audits, when conducted, were at the time of closure and not at regular intervals throughout the life of mine. The lack of clear lines of authority and responsibility, between the DME, DEA and DWA, regarding closure and environmental matters was also said to have hamstrung government officials from implementing ongoing audit and oversight programs pertaining to mines’ closure. This may also result in a lack of well-defined lines of communication, and consequent ‘mixed messages’ between government and mine operators which frustrates an unambiguous and productive closure planning process.

4.7 CONCLUSIONS

South African mine closure experts operate extensively in the field of mine closure throughout the mine life cycle, from baseline assessments to post-closure monitoring (See Table 5). There are significant mine closure opportunities in South Africa, and closure experts are working to address these issues. That is to say, there is significant experience and expertise available. However, the prospect of sustainable closure is obfuscated by poorly conducted baseline environmental studies and long term trials; less than comprehensive environmental indicator monitoring; ineffective stakeholder engagement; weak closure plans lacking top management commitment; and importantly, unstable environmental-mining legislation that weakens efforts which strive for sustainable closure.
CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

Mining is a temporary land use; and mine closure has proven, both worldwide and in South Africa, to be problematic in its sustainability as discussed in the literature review (Chapter 2). Based on a survey of professional mine closure specialists in South Africa, specific details regarding the frequent inadequacies of baseline and operational environmental indicators have been revealed and discussed (Chapter 4). It can be concluded that there is significant negative sentiment regarding the challenges of mine closure in South Africa. However, there are also proven mechanisms to engender successes in South African mine closure. Were all role players in South Africa to endeavour to implement such measures throughout mining, with an ethic of ‘mining for closure’, then the ideal of sustainable closure may in fact be achievable.

Thus, the objective of this chapter is to attempt to address the identified shortcomings in the realisation of sustainable mine closure in South Africa, by developing an environmental sustainability indicator framework; which if applied, shall address said gaps between mine closure sustainability policy and current mine closure practice in South Africa. As per the objectives of this study (Section 1.2), this chapter shall identify and summarise the gaps between policy (as per Chapter 2) and the status quo of South African mine closure (Chapter 4). It shall then provide an environmental sustainability indicator framework (linked to the sustainability principles developed in Table 3), which, if implemented aims to guide the trajectory of a mine site towards sustainable closure. Supplementary recommendations are also then made. Finally, the success of this study having met the initial research objectives shall briefly be discussed, followed by suggestions for further research.

5.2 IDENTIFIED GAPS BETWEEN POLICY, LEGISLATION AND CLOSURE PRACTICE

As stated in the objectives of this research (Section 1.2), it was deemed necessary to identify the gaps between sustainability policy and South African mine closure legislation, as well as the gaps between these presumably legislated principles and the ‘on-the-ground’ implementation thereof (status quo), as determined by the survey of closure experts. The identification of these shortcomings are evidenced in Table 8 below.
Table 8: The ratification of sustainability principles in South African legislation and the shortcomings of the ‘on-the –ground’ implementation thereof.

<table>
<thead>
<tr>
<th>Key Sustainable Development Principle §</th>
<th>Ratification in South African Legislation #</th>
<th>South African Mining Industry Status Quo and Shortcomings^</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Precautionary principle</strong></td>
<td>NEMA Section 2(4)(a)(vii, viii), 2(4)(r), 23(2)(c) GN R527 Section 63 NWA Section 19 (1)</td>
<td>Due to the licencing of mining rights and closure, and the associated environmental reports and plans, a precautionary stance is taken. However, as baseline studies and closure plans can be weak, the precautionary principle is not effected stringently enough.</td>
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<tr>
<td>2. Ethical corporate responsibility, community engagement and reporting</td>
<td>NEMA Section 2(2), 2(4)(c, d, e, k, l, o), 23(2)(d) MPRDA Sections: 2(i), 5A(a), 10(b), 16(4)(b), 19(2)(d, e), 22(4)(b), 25(1)(e), 27(5)(a, b) GN R527 Section 3, 41, 45</td>
<td>Consultation and public participation is legally required in the application for a mining licence and closure certificate. However, during the operational phase mines do not adequately engage communities in establishing a final land use and developing the closure plan to attain sustainable closure.</td>
</tr>
<tr>
<td>3. <strong>Subsidiarity principle and underpinning decision making</strong></td>
<td>NEMA Section: 2(2)(c, d), 2(4)(f, g, h, i), 23(1, 2) MPRDA Sections: 2(i), 10(2), 37</td>
<td>Despite sustainable development principles being embedded in the legislation, mines plans and operations are primarily driven by economic goals, steered by top management, while sustainable closure is relegated till it is too late for it to be effectively implemented.</td>
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<tr>
<td>4. <strong>Extensive Risk Management</strong></td>
<td>NEMA Section 2(4)(a)(vii), (i), 23(2)(b, e, f) MPRDA Section 16(4)(a), 22(4)(a) GN R527 Section 48, 49, 50, 51, 52, 56, 60, 61, 64, 68, 70, 73</td>
<td>The Environmental Management and Closure Plans required by the legislation entail a risk management approach. However, with weak baseline studies, risks are inadequately identified and poorly managed.</td>
</tr>
<tr>
<td>5. <strong>Internalisation of costs</strong></td>
<td>NEMA Section 2: (4)(p) MPRDA Section 43(1, 6), 45, 46(2) GN R527 Section 54, 61 NWA Section 19(5)</td>
<td>The principle of ‘polluter pays’ is embedded in the legislation, however a proper accounting of such costs is difficult and rarely effected.</td>
</tr>
<tr>
<td>6. <strong>Iterative planning, monitoring and continual improvement</strong></td>
<td>NEMA Section 2(4)(e), 23(2)(f) GN R527 Section 55, 56</td>
<td>With a closure certificate being near impossible to obtain in South Africa, mines are disincentivised to implement extensive environmental monitoring to direct the mine operations toward sustainable closure.</td>
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<tr>
<td>7. <strong>Investment in research and development and capacity building</strong></td>
<td>NEMA Section 2: (4)(b, h, q)</td>
<td>There is a weakness in the legislative mandate for the necessity of long term research and the trial of closure options. This extends to human resource (and community/ government) capacity development in this respect. These legislative weaknesses are seen in the ‘on-the-ground’ status quo.</td>
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<td>8. <strong>Rehabilitation, appropriate land use and local sustainability</strong></td>
<td>NEMA Section 2: (3), (4)(a)(i, ii, iii, v) MPRDA 43(11, 12), 48(2)(a, b) GN R527 Section 56, 61, 62 NWA Section 19(2)</td>
<td>Such rehabilitation and land use considerations are included in the legislation, however with weak baseline assessments and closure plans, the practical execution is often poor.</td>
</tr>
<tr>
<td>9. <strong>Systems approach and interconnected-ness of principles</strong></td>
<td>NEMA Section 2: (4)(a, b) MPRDA Section 37, 43(9, 10) GN R527 Section 56</td>
<td>The principle of a systems approach is integrated into the legislation, however it is not seen to be effected beyond being a guiding principle. Likewise that these principles themselves are interconnected is acknowledged in the legislation, however there is little practical application thereof.</td>
</tr>
<tr>
<td>10. <strong>Waste as a resource: Greening a circular economy</strong></td>
<td>NEMA Section 2: (4)(a)(iv) MPRDA Section 2(e) GN R527 Section 63, 69</td>
<td>Although waste reuse is included in the legislation, the principle of a green circular economy is not strongly effected in either the legislation or practice.</td>
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As per Table 3 in Section 2.3.5
* South African mine closure legislation identified in Section 4.6.1
\(^{a}\) Based on Chapter 4: Results and Discussion.

In Table 8 above, each sustainability principle has been reviewed and matched with sections of South African mining legislation which embody or incorporate these principles. It can thus be seen that sustainability considerations are well embedded and ratified by South African mining and environmental legislation. As mentioned in Section 2.6.4, there are however some areas of weakness in the legislation. These legislated aspects are then (in the third column of Table 8) compared with the current status quo of mine closure and sustainability as determined by the survey conducted in Chapter 3, the results of which are discussed in Chapter 4. What is thus evident is a failure to fully implement these principles in reality, despite them being relatively well embedded in the legislation. Although already mentioned in Chapter 4, it is again evidenced here, that a major shortcoming in achieving sustainable mine closure in South Africa is the instability of mining legislation, and a consequent poor implementation of said legislation, notwithstanding its incorporation of sustainability principles.
5.3 RECOMMENDATIONS

The prime recommendations of this research are threefold; firstly, an indicator framework (based on sustainable development principles in Table 3) has been developed to guide mine operations toward sustainable closure. Secondly, a conceptual framework which extends beyond indicator monitoring, and seeks to direct the totality of the mine closure process iteratively towards the goal of sustainable closure, is also put forward. Lastly it is strongly advocated that for South African mines to move toward achieving sustainable closure, a clear and stable legislative environment is an absolute necessity.

5.3.1 An Indicator Framework Developed to Address the Gaps Between Mining Sustainability Policy and Current Mine Closure Practice in South Africa

As previously discussed (Section 2.4.2), it is sustainability principles which support and guide the realisation of mining’s positive contribution to sustainable development, which culminates in sustainable mine closure. An initial objective of this research (Section 1.2) was to develop environmental indicators of sustainability (aligned with the recommendations of closure experts from Section 4.3). As per the theory regarding developing indicator frameworks discussed in Section 2.5, these indicators are based on the previously collated list of ‘sustainability principles’ developed in Section 2.3.5, as well as linked to corresponding ‘objectives of closure’ (as per Section 2.4.2.1). This indicator framework is thus presented below in Table 9.
Table 9: An environmental sustainability indicator framework to address the gaps between mine closure sustainability policy and current mine closure practice in South Africa.

<table>
<thead>
<tr>
<th>Key Sustainable Development Principle</th>
<th>Goals and Objectives of Closure</th>
<th>Indicators of Implementation of Sustainability Principles and Closure Objectives to Support Environmentally Sustainable Closure</th>
</tr>
</thead>
</table>
| 1. Precautionary principle           | Securing the site for any future land use and/or reverting to a premining state, which can tolerate a range of climate change scenarios | • Baseline and trade-off studies are conducted.  
• Pre-mining state established such as to set linked environmental sustainability goals to rehabilitate to. Performance against goals monitored.  
• Environmental thresholds established to inform decision making. Thresholds monitored and precautionary measures taken if thresholds are approached. Cumulative and regional impacts are identified and monitored.  
• Identify sensitive areas, habitats, species – implement proactive management in a precautionary manner. Key indicators established to monitor fragility. |
| 2. Ethical corporate responsibility, community engagement and reporting | Socio-economic sustainability | • Closure planning integrates community engagement. A shared closure vision (including an environmentally sustainable land use) is developed and refined throughout life of mine.  
• Implement regular and transparent environmental sustainability and closure reporting and invite feedback from the public. |
| 3. Subsidiarity principle and underpinning decision making | Socioeconomic sustainability as well as physical, chemical and biological stability which ensures a sustainable land use | • Findings and management actions of environmental baseline studies and EIA’s are integrated into both mine and closure planning; such linkages are clearly documented and reported on.  
• Sustainable closure planning requires inputs from all levels of the business (rehab operators, environmental and mine planning staff, through mine management across all departments, and including corporate management) as well as local communities; such considerations are documented and actioned.  
• All major decision making takes environmentally sustainable closure into account; such considerations are documented and results monitored. |
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</table>
| **4. Extensive Risk Management** | Physical, chemical and biological stability | • Conduct regular risk reviews as well as risk reviews triggered by major mine plan changes.  
• Each risk is linked to mitigatory management action plans, and progress is monitored through an EMS.  
• Environmental risk profile trends are monitored over time and feed into future planning and decision making. |
| **5. Internalisation of costs** | Financially achievable closure | • Negative impacts (social and environmental) are quantified and included in costing of mine closure.  
• Such costings are done on a regular basis; trends monitored which in turn inform decision making. |
| **6. Iterative planning, monitoring and continual improvement** | Physical, chemical and biological stability as well as socio-economic sustainability at closure | • Continual improvement programs demonstrate the improvement of environmental and social indicators. Such trends are monitored and inform decision making. Moreover, indicators themselves are refined as studies provide better knowledge regarding risks. |
| **7. Investment in research and development and capacity building** | A sustainable and productive post-closure land use | • Long term scientifically rigorous trials are essential to inform final sustainable land use potential. Such trials are established and monitored.  
• Similarly, social resources are developed with performance management measures in place to ensure efficacy and value add toward closure objectives. |
| **8. Rehabilitation, appropriate land use and local sustainability** | Physical, chemical and biological stability as well as socio-economic sustainability at closure | • Ongoing monitoring of environmental indicators is imperative to inform decision making and maintain alignment with final land use. Cognisance of source/pathway/receptor informs indicator selection.  
• Environmental indicators classes which require monitoring include:  
  • Water (e.g. surface and underground, quality and quantity, predictive modelling)  
  • Soil (e.g depth, structure, nutrient capacity/fertility, erodability)  
  • Land use (e.g topography, rehabilitation status, capacity to meet end land use)  
  • Biodiversity (e.g. species and ecosystem establishment, basal cover, alien invasives)  
  • Air (e.g PM10 and 2.5 dust, NO\(_x\), SO\(_x\)) |
9. **Systems approach and interconnected-ness of principles**

| The establishment of sustainable human-natural systems post-closure | • It is necessary to identify the causal relationships between environmental aspects, as well as between social and economic considerations in a systems approach. The state of these relationships is itself an indicator of the balance of the whole system, and thus is to be monitored.  
• Such systems thinking is also applied from the ground-up in mine design, such that material changes may be monitored for their causal impacts, and consequently managed.  
• Indicators, and the relationships / dependencies between them, are identified such that meta-indicators are developed which indicate system state change. |

10. **Waste as a resource: Greening a circular economy**

| Future public health and safety is not compromised and socio-economic benefits are maximised | • The volumes and impacts (air, water, land etc.) of mining wastes are measured and monitored. The ‘sustainability costs’ of these wastes (including avoidance, rehabilitation, land use loss, water pollution, amelioration etc.) are accounted for, against repurposing/reprocessing the wastes to minimise/negate the negative impacts thereof. |

*As per Table 3 in Section 2.3.5*  
^After Section 2.4.2.1  
*As per international best practice (Section 2.3) and South African closure experts (Section 4.3)*

Table 9 provides a broad environmental sustainability indicator framework, as each operation is site specific in its impacts. By analysing an operation’s environmental aspects and impacts and developing site specific indicators based on the above framework (underpinned by sustainability principles and designed to meet the criteria specified in Section 2.5.1), the mine site will be enabled to guide its decision making and ultimate trajectory toward an environmentally sustainable closure. These indicators would have to be embedded in a mine’s EMS to be effectively implemented; which in itself would require top-management commitment to these sustainability principles and indicators.

### 5.3.2 Other Recommendations

The desired research objective of creating an indicator framework which indicates the trajectory of a mine site toward or away from closure has been presented in Section 5.3.1 above. However, in the course of this research two other key recommendations have been arrived at.
Figure 14 below illustrates the first: an idealised conceptual framework for driving sustainable closure decision making and guiding an iterative closure process.

The development of Figure 14 has been based on the survey responses received and closure literature reviewed. It can be seen that detailed baseline assessments are an imperative in underpinning an effective closure plan. This must then translate into comprehensive operational environmental monitoring (and long term trials) which recursively advance decision making toward a sustainable end land use. Such data should be accurate, reliable, frequent and well managed. Concurrently rigorous liability costings must be conducted and transparent financial provision be made accordingly, that the necessary closure remediation may be executed. Further to this, continuous (as well as optimally informed and designed) rehabilitation must take place as mining advances, such that the final restoration does not constitute an unmanageable cost. Ongoing monitoring (of adherence to sustainability principles as directed by the indicator framework proposed in Table 9), will timeously identify shortfalls in the arriving at sustainable closure. These identified gaps can then be addressed by further studies and consequent implementation of recommended actions to best realign with the
trajectory of sustainable closure. That is to say, iteratively, this cycle seeks to continually readjust mine closure decision making to gaps from monitoring, learnings from consequent research and costings, ongoing inputs from stakeholders and the progress of operational rehabilitation.

It is also an evident essential to (internally) garner senior mine management’s buy-in to ensure long term commitment to, and driving of, ‘mining for closure’. This theme of communication and cooperation can and should be extended across all stakeholder interactions and relations. Corporate management can beneficially take a close interest in operations’ closure performance, both to support and ensure compliance to high standards of closure planning and execution. Mining operations should early on establish meaningful closure dialogue with government and local communities. These discussions (in conjunction with environmental studies) can best align, inform and manage, the expectations, objectives and outcomes, of the final land use. Public-private partnerships have been shown to produce win-win solutions to mine closure challenges in South Africa (Hobbes et al, 2008).

The second additional key recommendation of this research is levelled at the mining legislative milieu. The legislation is in dire need of internal coherence and long term stability. Without this, certified mine closure remains unachievable and is thus perceived as ‘not worth striving for’. There are no advantageous reasons as to why the DMR should be the responsible licencing authority for environmental aspects of mining. Moreover this can be construed as a conflict of interest with the DMR issuing both mining and environmental authorisations. No other industry has such exception, that is to say, the DEA is the environmental licencing authority for all other industries (e.g. construction, forestry etc). The DEA is also better capacitated to evaluate environmental applications than the DMR (CER, 2013). Thus environmental legislation is undermined by this ‘in flux’ environmental licencing responsibility which currently lies between the two departments (Humby, 2014). Moreover government departments must practice cooperative governance such that the DMR, DWA and DEA share a common vision of closure and reinforce the sustainable development of South African mineral resources (CER, 2012). Without this foundation, and enforceable compliance to environmental sustainability, sustainable and certified closure remains a vague ideal and not a practicality which mining companies could desire to strive for.

5.4 SUCCESS OF MEETING INITIAL RESEARCH OBJECTIVES

This brief section will revisit the research objectives which were clearly laid out in Section 1.2 at the inception of this study, and elucidate how, through this study, each objective has been met. Table 10 below presents this summation.
Table 10: Summary of the fulfilment of research objectives.

<table>
<thead>
<tr>
<th>Research Objective</th>
<th>Fulfilment of Research Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i). Document current global, and South African, best practice regarding environmental principles and indicators of sustainable development in mining.</td>
<td>The literature review (Chapter 2) addresses this objective in detail, and culminates in a synthesis of this research (Section 2.7.1), and a consolidated table of principles of sustainable development in mining (Table 3 in Section 2.3.5).</td>
</tr>
<tr>
<td>(ii). Evaluate South African mine closure legislation against aforementioned environmental principles and indicators of sustainable development.</td>
<td>An initial evaluation of South African mine closure legislation is conducted in Section 2.6, while an in-depth analysis of the embedding of sustainability principles is presented in Table 8 (see Section 5.2).</td>
</tr>
<tr>
<td>(iii). Survey current mining industry best practice in South Africa, with respect to the support of sustainable closure by means of environmental indicators founded in sustainable development.</td>
<td>The methodology of the survey conducted regarding objective (iii) is presented in Chapter 3, while the results thereof are detailed and discussed in Chapter 4.</td>
</tr>
<tr>
<td>(iv). Define the gap between South African mine closure legislation (ii) and the South African mine closure status quo (iii), within the context of sustainable development principles (i).</td>
<td>Table 8 (see Section 5.2), finds that the consolidated list of sustainability in mining principles (from Table 3 in Section 2.3.5), are well embedded within South African mine closure legislation, and then identifies the gaps between this and ‘South African closure practice’ as evidenced by the experts surveyed.</td>
</tr>
<tr>
<td>(v). Propose a framework of environmental sustainability indicators to address the gap defined above (iv).</td>
<td>Table 9 (see Section 5.3.1) links the sustainability in mining principles (from Table 3 in Section 2.3.5) with objectives of closure (detailed in Section 2.4.2.1) and proposes environmental sustainability indicators to measure the alignment with these principles and objectives of sustainable closure, which if implemented would address the gaps identified in objective (iv).</td>
</tr>
</tbody>
</table>
5.5 SUGGESTIONS FOR FURTHER RESEARCH

What can be perceived in the outcomes of this research, is the high level of the indicator framework developed from the literature reviewed and the survey responses at hand. This indicator framework, though meeting the overarching aim of the research, lacks specific detail. This detail is however, for all intents and purposes, unavailable without a conducting a site specific case study. Thus, it is the first recommendation of this research, that the indicator framework (Table 9 in Section 5.3.1) be trialled at an operating mining site, and thus refined through the iterative process put forward in Figure 14 (Section 5.3.2). Secondly, as delineated in Section 1.3, this study set out to limit itself to the environmental aspects of mine closure. Consequently the indicator framework developed has centred around targeting environmental sustainability post-closure. However, due to the interconnected nature of sustainability principles upon which the proposed environmental sustainability indicator framework is based, social and economic aspects are necessarily included, albeit at a less detailed level. There is thus place for further research, focusing on socioeconomic sustainability post-closure, by which the proposed indicator framework may further be refined and added to; thereby making it a more holistic and robust life of mine ‘closure-monitoring’ and ‘trajectory-directing’ sustainability solution.
REFERENCES


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APPENDIX A: MASTER QUESTIONNAIRE

M – Mining Site
C – Corporate
Co – Consultant
G – Government
A – Academic
L – Legal

(NOTE: Participants are piped accordingly to tailored questions as designated below by curly brackets)

1. In which mineral/s does your closure experience lie? {All}
2. In which area does your mine closure experience primarily lie: Mine Site, Corporate, Consultant, Government, Academic, Legal? {All}
3. What mineral type is being mined and with what mining method? {M, C}
4. Total Tons Moved (TTM) and Run of Mine (ROM) p.a.? {M, C}
5. Is ROM processed on-site? {M, C}
6. What environmental indicators are monitored beyond the mine boundary? {M, C}
7. What year did mining start? {M, C}
8. What is the expected remaining Life of Mine (LOM)? {M, C}
9. What baseline (pre-mining) environmental indicators exist? {M, C, Co, G}
10. Full list of environmental indicators currently measured (by class: water, land, air, other). {M, C, Co, G}
11. What would be the ideal list of environmental indicators measured to support sustainable closure. {M, C, Co, G, A, L}
12. Is there an up to date closure plan in place and is it reported upon? {M, C – regarding all operations?; Co – Can you estimate from your experience, when consulting on closure, what is the proportion of mines with closure plans in place; G – the mines you are responsible for have closure plans?}
13. Which phase/s of mine closure have you participated in? {M, C, Co, G, A, L}
14. Please detail specific successes you have encountered in mine closure {M, C, Co, G, A, L}
15. Please detail specific successes you have encountered in mine closure {M, C, Co, G, A, L}
16. In your opinion, what are the most important ideal environmental indicators with respect to closure? {M, C, Co, G, A, L}
17. Which South African closure legislation are you aware of? {M, C, Co, G, A, L}
18. What other environmental investigations do you consider imperative for closure? {M, C, Co, G, A, L}
19. Do closure indicators/plans roll up into divisional corporate reporting on Sustainable Development? {M, C}
20. Do environmental indicators relate to the planned final land use? {M, C, Co, G}
APPENDIX B: APPLICABLE MINE CLOSURE EXCERPTS FROM SOUTH AFRICAN LEGISLATION

[As last amended by National Environmental Laws Amendment Act 14 of 2009.]

S24(5) The Minister, or an MEC with the concurrence of the Minister, may make regulations consistent with subsection (4):
...
(b) laying down the procedure to be followed in respect of:
...
(viii) mine closure requirements and procedures, the apportionment of liability for mine closure and the sustainable closure of mines with an interconnected or integrated impact resulting in a cumulative impact;
(ix) financial provision;

S24N Minister of Minerals and Energy, an MEC or identified competent authority must require the submission of an environmental management programme before considering an application for an environmental authorisation.
(2) The environmental management programme must contain:
...
(v) closure, if applicable;

S24P. Financial provision for remediation of environmental damage
(1) An applicant for an environmental authorisation relating to prospecting, mining, exploration, production or related activities on a prospecting, mining, exploration or production area must make the prescribed financial provision for the rehabilitation, management and closure of environmental impacts, before the Minister of Minerals and Energy issues the environmental authorisation.

S24R. Mine closure on environmental authorisation
(1) Every holder, holder of an old order right and owner of works remain responsible for any environmental liability, pollution or ecological degradation, the pumping and treatment of extraneous water, the management and sustainable closure thereof until the Minister of Minerals and Energy has issued a closure certificate in terms of the Mineral and Petroleum Resources Development Act, 2002, to the holder or owner concerned.
(2) When the Minister of Minerals and Energy issues a closure certificate, he or she must return such portion of the financial provision contemplated in section 24P as the Minister may deem appropriate to the holder concerned, but may retain a portion of such financial provision for any latent and or residual environmental impact that may become known in the future.
(3) Every holder, holder of an old order right or owner of works must plan, manage and implement such procedures and requirements in respect of the closure of a mine as may be prescribed.
(4) The Minister may, in consultation with the Minister of Minerals and Energy and by notice in the Gazette, identify areas where mines are interconnected or their impacts are integrated to such an extent that the interconnection results in a cumulative impact.
(5) The Minister may, by notice in the Gazette, publish strategies in order to facilitate mine closure where mines are interconnected, have an integrated impact or pose a cumulative impact.
[As last amended by the Mineral and Petroleum Resources Development Amendment Act 49 of 2008.]

S43. Issuing of a closure certificate
(1) The holder of a prospecting right, mining right, retention permit, mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, remains responsible for any environmental liability, pollution, ecological degradation, the pumping and treatment of extraneous water, compliance to the conditions of the environmental authorisation and the management and sustainable closure thereof, until the Minister has issued a closure certificate in terms of this Act to the holder or owner concerned.
(2) On the written application in the prescribed manner by the holder of a prospecting right, mining right, retention permit, mining permit or previous holder of an old order right or previous owner of works that has ceased to exist, the Minister may transfer such environmental liabilities and responsibilities as may be identified in the environmental management report and any prescribed closure plan to a person with such qualifications as may be prescribed.
(3) The holder of a prospecting right, mining right, retention permit, mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, or the person contemplated in subsection (2), as the case may be, must apply for a closure certificate upon:
   (a) the lapsing, abandonment or cancellation of the right or permit in question;
   (b) cessation of the prospecting or mining operation;
   (c) the relinquishment of any portion of the prospecting of the land to which a right, permit or permission relate; or
   (d) completion of the prescribed closing plan to which a right, permit or permission relate.
(4) An application for a closure certificate must be made to the Regional Manager in whose region the land in question is situated within 180 days of the occurrence of the lapsing, abandonment, cancellation, cessation, relinquishment or completion contemplated in subsection (3) and must be accompanied by the required information, programmes, plans and reports prescribed in terms of this Act and the National Environmental Management Act, 1998.
(5) No closure certificate may be issued unless the Chief Inspector and each government department charged with the administration of any law which relates to any matter affecting the environment have confirmed in writing that the provisions pertaining to health and safety and management pollution to water resources, the pumping and treatment of extraneous water and compliance to the conditions of the environmental authorisation have been addressed.
(5A) Confirmation from the Chief Inspector and each government department contemplated in subsection (5) must be received within 60 days from the date on which the Minister informs such Chief Inspector or government department, in writing, to do so.
(6) When the Minister issues a certificate he or she must return such portion of the financial provision contemplated in section 41 the National Environmental Management Act, 1998, as the Minister may deem appropriate, to the holder of the prospecting right, mining right, retention permit or mining permit, previous holder of an old order right or previous owner of works or the person contemplated in subsection (2), but may retain any portion of such financial provision for latent and residual safety, health or environmental impact which may become known in the future.
(7) The holder of a prospecting right, mining right, retention permit, mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, or the person contemplated in subsection (2), as the case may be, must plan for, manage and implement such procedures and such requirements on mine closure as may be prescribed.
(8) Procedures and requirements on mine closure as it relates to the compliance of the conditions of an environmental authorisation, are prescribed in terms of the National Environmental Management Act, 1998.
(9) The Minister, in consultation with the Minister of Environmental Affairs and Tourism, may identify areas by notice in the Gazette, where mines are interconnected or their safety, health, social or environmental impacts are integrated which results in a cumulative impact.

(10) The Minister may, in consultation with the Minister of Environmental Affairs and Tourism, publish by notice in the Gazette, strategies to facilitate mine closure where mines are interconnected, have an integrated impact or pose a cumulative impact.

(11) The holder of a prospecting right, mining right, retention permit, mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, or the person contemplated in subsection (2), as the case may be, operating or who has operated within an area identified in subsection (9), must amend their programmes, plans or environmental authorisations accordingly or submit a closure plan, subject to the approval of the Minister, which is aligned with the closure strategies contemplated in subsection (10).

(12) In relation to mines with an interconnected or integrated health, safety, social or environmental impact, the Minister may, in consultation with the Minister of Environmental Affairs and Tourism, determine the apportionment of liability for mine closure as prescribed.

(13) No closure certificate may be issued unless:
(a) the Council for Geoscience has confirmed in writing that complete and correct prospecting reports in terms of section 21(1) have been submitted to the Council for Geoscience;
(b) the complete and correct records, borehole core data or core-log data that the Council of Geoscience may deem relevant, have been lodged with the Council for Geoscience; or
(c) in the case of the holder a permit or right in terms of this Act, the complete and correct surface and the relevant underground geological plans have been lodged with the Council for Geoscience.

S52 (4) The holder of a mining right remains responsible for the implementation of the processes provided for in the Labour Relations Act, 1995 (Act 66 of 1995), pertaining to the management of downscaling and retrenchment, until the Minister has issued a closure certificate to the holder concerned.

[As last amended by the National Water Amendment Act 45 of 1999.]

S19. Prevention and remedying effects of pollution
(1) An owner of land, a person in control of land or a person who occupies or uses the land on which:
(a) any activity or process is or was performed or undertaken; or
(b) any other situation exists, which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.

(2) The measures referred to in subsection (1) may include measures to:
(a) cease, modify or control any act or process causing the pollution;
(b) comply with any prescribed waste standard or management practice;
(c) contain or prevent the movement of pollutants;
(d) eliminate any source of the pollution;
(e) remedy the effects of the pollution; and
(f) remedy the effects of any disturbance to the bed and banks of a watercourse.
Principles for mine closure

56. In accordance with applicable legislative requirements for mine closure, the holder of a prospecting right, mining right, retention permit or mining permit must ensure that –

(a) the closure of a prospecting or mining operation incorporates a process which must start at the commencement of the operation and continue throughout the life of the operation;

(b) risks pertaining to environmental impacts must be quantified and managed pro-actively, which includes the gathering of relevant information throughout the life of a prospecting or mining operation;

(c) the safety and health requirements in terms of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996) are complied with;

(d) residual and possible latent environmental impacts are identified and quantified;

(e) the land is rehabilitated, as far as is practicable, to its natural state, or to a predetermined and agreed standard or land use which conforms with the concept of sustainable development; and

(f) prospecting or mining operations are closed efficiently and cost effectively.

Application for closure certificate

57. (1) An application for a closure certificate by the holder of a prospecting right, mining right, retention permit or mining permit in terms of section 43(4) of the Act must be completed in the form of Form P, contained in Annexure II.

(2) The application referred to in subregulation (1) must be accompanied by the following documentation –

(a) A closure plan contemplated in regulation 62;

(b) an environmental risk report contemplated in regulation 60;

(c) a final performance assessment report contemplated in regulation 55(9); and

(d) a completed application form contemplated in regulation 58(1) to transfer environmental liabilities and responsibilities, if the transfer of such liabilities have been applied for.
Environmental risk report

60. An application for a closure certificate must be accompanied by an environmental risk report that must include-

(a) the undertaking of a screening level environmental risk assessment where-
   (i) all possible environmental risks are identified, including those which appear to be insignificant;
   (ii) the process is based on the input from existing data;
   (iii) the risks that are considered are qualitatively ranked as –
      (aa) a potential significant risk;
      (bb) a uncertain risk;
      (cc) an insignificant risk;

(b) the undertaking of a second level risk assessment on issues classified as potential significant risks where-
   (i) appropriate sampling, data collection and monitoring be carried out;
   (ii) more realistic assumptions and actual measurements be made; and
   (iii) a more quantitative risk assessment is undertaken, again classifying risks as posing a potential significant risk or insignificant risk.

(c) an assessment of whether risks classified as posing potential significant risks are acceptable without further mitigation;

(d) risks classified as uncertain risks be re-evaluated and re-classified as either posing potential significant risks or insignificant risks;

(e) documenting the status of insignificant risks;

(f) identifying alternative risk prevention or management strategies for potential significant risks that have been identified, quantified and qualified in the second level risk assessment; and

(g) agreeing on management measures to be implemented for the potential significant risks that must include-
   (i) a description of the management measures to be applied;
   (ii) a predicted long-term result of the applied management measures;
   (ii) the residual and latent impact after successful implementation of the management measures;
   (iii) time frames and schedule for the implementation of the management measures;
   (iv) responsibilities for implementation and long-term maintenance of the management measures;
   (v) financial provision for long-term maintenance; and
   (vi) monitoring programmes to be implemented.
**Closure objectives**

61. Closure objectives form part of the draft environmental management programme or environmental management plan, as the case may be, and must –

   (a) identify the key objectives for mine closure to guide the project design, development and management of environmental impacts;

   (b) provide broad future land use objective(s) for the site; and

   (c) provide proposed closure costs.

**Contents of closure plan**

62. A closure plan contemplated in section 43(3)(d) of the Act, forms part of the environmental management programme or environmental management plan, as the case may be, and must include –

   (a) a description of the closure objectives and how these relate to the prospecting or mine operation and its environmental and social setting;

   (b) a plan contemplated in regulation 2(2), showing the land or area under closure;

   (c) a summary of the regulatory requirements and conditions for closure negotiated and documented in the environmental management programme or environmental management plan, as the case may be;

   (d) a summary of the results of the environmental risk report and details of identified residual and latent impacts;

   (e) a summary of the results of progressive rehabilitation undertaken;

   (f) a description of the methods to decommission each prospecting or mining component and the mitigation or management strategy proposed to avoid, minimize and manage residual or latent impacts;

   (g) details of any long-term management and maintenance expected;

   (h) details of a proposed closure cost and financial provision for monitoring, maintenance and post closure management;

   (i) a sketch plan drawn on an appropriate scale describing the final and future land use proposal and arrangements for the site;

   (j) a record of interested and affected persons consulted; and

   (k) technical appendices, if any.