

**DEVELOPING A GENERIC MODEL OF THE  
INITIAL REVIEW PROCESS  
FOR A GOLD MINE SHAFT BUSINESS UNIT**

**Theunis Christoffel Meyer**

**M.Sc. Agric. (Pasture Science), B.Sc. Hons. (Wildlife Management)**

Dissertation submitted in the School of Environmental Sciences and Development,  
Potchefstroomse Universiteit vir Christelike Hoër Onderwys  
in partial fulfilment of the requirements of the degree Magister Environmental Management

**Supervisor: Prof. I.J. van der Walt**

**POTCHEFSTROOM**

**2003**

---

## **Preface**

I would like to thank:

- Prof. I.J. van der Walt for his supervision and motivation.
- Prof. J.G. Nel for sharing his knowledge and experience.
- AngloGold Ltd. for the opportunity to undertake this study and allowing me access to their operations and documentation, especially messrs Steve Bullock, Henk Jonker, Hannes Potgieter and Ulrich Sibilski.
- My parents, for their unconditional trust and encouragement in all my endeavours.
- My parents-in-law for their moral support and understanding.
- Susan, who patiently supported me and often had to cope alone in my absence. Without her support and understanding, I would not have been able to achieve this.
- Carina and Elmi, who became accustomed to weekends and holidays without their father.

Above all, I thank the Lord who gives me all I need and holds my life in his hands. "How wonderful are your gifts to me, how good they are!"

## **Abstract**

South Africa is one of the world's foremost mining nations and mining and its associated industries continue to form the cornerstone of the country's economy. However, the mining industry has, by its very nature, the potential to endanger human health and safety, as well as the physical environment. Consequently, mining will always contend with major environmental challenges and remain under constant public pressure to demonstrate its commitment to responsible environmental management.

The key to effective environmental management is the use of a systematic approach to plan, control and improve environmental efforts. An Environmental Management System (EMS) employs such an approach and allows organisations to address environmental concerns in an orderly and consistent manner. Such a system allows organisations to anticipate and meet their environmental objectives and to ensure ongoing compliance with national and/or international requirements.

An organisation with no existing EMS should, initially, establish its current position with regard to the environment by means of an initial review process. The aim should be to consider all environmental aspects of the organisation as a basis for establishing the EMS.

Although a few gold mines in South Africa have implemented an EMS, the question of which significant environmental aspects need to be managed in such a system at a deep level gold mine shaft, remains largely unanswered. This study endeavoured to provide answers to this question and develop a generic model for the initial review process of a deep level gold mine shaft. The development of such a model should facilitate the development and implementation of an EMS at such shafts, thereby contributing to reduce the environmental impact of gold mines.

The research consisted of a literature review of national and international literature on the topic and a comparative empirical study, which evaluated the mining operations of two deep level gold mine shafts. Data collection and analysis was done according to the ISO 14015 guideline on the environmental assessment of sites and organisations. Other techniques used included business process analysis, the use of modified Leopoldt matrices and risk analysis to determine the significance of the environmental impacts and aspects.

This study contributed to a generic model for the initial environmental review process that precedes the development of an EMS at deep level gold mine shafts through:

- developing a generic sub-model that can be used to determine the scope of any deep level gold mine shaft;

- identifying some of the significant environmental impacts and aspects of deep level gold mine shafts, as well as
- identifying some generic business activities that are potentially destructive and carry a high risk of causing significant negative environmental impacts.

**Key words:** environmental impact, environmental aspect, environmental management system, initial review process, gold mine shaft, ISO 14001

# **ONTWIKKELING VAN 'N GENERIESE MODEL VAN DIE AANVANKLIKE BASISLYN OPNAME VIR 'N GOUDMYNSKAG BESIGHEIDSEENHEID**

## **Opsomming**

Suid-Afrika is een van die wêreld se voorste mynbounasies en mynbou met sy geassosieerde industrieë bly steeds een van die hoekstene van die land se ekonomie. Die aard van mynbou-aktiwiteite is egter sodanig dat dit 'n potensiële bedreiging inhou vir menslike gesondheid en veiligheid, sowel as die fisiese omgewing. Gevolglik sal mynbou altyd met omgewingsuitdagings worstel en onder konstante openbare druk verkeer om 'n verbintenis tot verantwoordelike omgewingsbestuur te demonstreer.

Die toepassing van 'n sistematiese benadering tot beplanning, beheer en verbeterde bestuur is die sleutel tot doeltreffende omgewingsbestuur. 'n Omgewingsbestuurstelsel (OBS) gebruik so 'n benadering en stel organisasies in staat om hulle omgewingskwessies op 'n ordelike en konsekwente wyse aan te spreek. So 'n stelsel stel organisasies ook in staat om hulle omgewingsdoelwitte te antisipeer en te bereik, asook om voortdurende nakoming van nasionale en internasionale vereistes te verseker.

In die afwesigheid van 'n bestaande OBS moet 'n organisasie aanvanklik eers sy huidige posisie ten opsigte van die omgewing bepaal deur middel van 'n basislyn-opname. Die doel daarvan moet wees om al die omgewingsaspekte van die organisasie te identifiseer en te evalueer as basis vir die ontwikkeling van 'n OBS.

Enkele goudmyne in Suid-Afrika het reeds 'n OBS geïmplementeer. Die vraag oor watter betekenisvolle omgewingsaspekte deur so 'n stelsel aangespreek moet word by 'n diep ondergrondse goudmynskag bly egter nog grootliks onbeantwoord. Hierdie studie het gepoog om daardie vraag te beantwoord en 'n generiese model vir die aanvanklike basislyn-opnameproses by 'n diep ondergrondse goudmynskag te ontwikkel. Die ontwikkeling van so 'n model kan die ontwikkeling en implementering van 'n OBS by sulke skagte 'n hupstoot gee en sodoende 'n bydrae lewer om die omgewingsimpakte van goudmyne te verminder.

Die navorsing het bestaan uit 'n literatuurondersoek van nasionale en internasionale bronne oor die onderwerp, gevolg deur 'n vergelykende empiriese studie, wat die mynbou-aktiwiteite van twee diep ondergrondse goudmynskagte geëvalueer het. Data-insameling en -analise

is aan die hand van die ISO 14015-ri glyne vir die omgewingsevaluering van terreine en organisasies gedoen. Ander tegnieke wat gebruik is, het besigheidproses-analise, die gebruik van aangepaste Leopoldt-matrikse en risiko-analises om die betekenisvolheid van omgewingsimpakte en –aspekte te bepaal, ingesluit.

Hierdie studie het op die volgende wyses 'n bydrae gelewer tot die ontwikkeling van 'n generiese model vir die aanvanklike basislyn-opnameproses wat die ontwikkeling van 'n OBS by diep ondergrondse goudmynskagte in Suid-Afrika voorafgaan:

- Daar is 'n generiese sub-model ontwikkel om die bestek/omvang van 'n diep, ondergrondse goudmynskag te beskryf in terme van die besigheidsprosesse, fisiese grense en personeelkomponent daarvan.
- Sommige betekenisvolle omgewingsimpakte en –aspekte van diep, ondergrondse goudmynskagte in Suid-Afrika is geïdentifiseer.
- Sommige generiese besigheidsaktiwiteite van diep, ondergrondse goudmynskagte in Suid-Afrika, wat potensieel skadelik is en 'n hoë risiko inhou om betekenisvolle negatiewe omgewingsimpakte te veroorsaak, is ook geïdentifiseer.

**Trefwoorde:** omgewingsimpak, omgewingsaspek, omgewingsbestuurstelsel, aanvanklike basislyn opnameproses, goudmynskag, ISO 14001

## **Contents**

<b>Preface.....</b>	<b>i</b>
<b>Abstract.....</b>	<b>ii</b>
<b>Opsomming.....</b>	<b>iv</b>
<b>Contents.....</b>	<b>vi</b>
<b>Chapter 1 - Introduction.....</b>	<b>1</b>
References.....	8
<b>Chapter 2.....</b>	<b>10</b>
Implementing Environmental Management Systems to improve sustainable development in gold mining: 1. Towards a generic scope for deep level gold mine shafts in South Africa. ...	10
Abstract.....	10
Uittreksel.....	11
1. Introduction.....	11
2. Study area.....	13
3. Research methods.....	13
4. Results.....	20
5. Conclusion.....	32
References.....	33
<b>Chapter 3.....</b>	<b>35</b>
Implementing Environmental Management Systems to improve sustainable development in gold mining: 2. Environmental impacts and aspects of deep level gold mine shafts in South Africa.....	35
Abstract.....	35
Uittreksel.....	36
1. Introduction.....	36
2. Study area.....	38
3. Experimental procedure.....	39
4. Results.....	49
5. Discussion.....	65
6. Conclusions.....	68
References.....	69
<b>Chapter 4 - Conclusions.....</b>	<b>75</b>

## **Chapter 1 - Introduction**

South Africa is one of the world's foremost and most diverse mining and mineral processing nations. The highly mineralised nature of many parts of South Africa has led to the creation of a mining industry which is very important to the country's economy. The mining industry is supported by an extensive and diversified resource base, which enabled South Africa to produce 55 different minerals from 713 mines and quarries and export mineral commodities to 87 countries in 2000 (Wells *et al.* 1992:362; Mbendi, 1997; Verster & Van Luitingh, 1997; Chamber of Mines of South Africa, 2002:2).

The mining industry in southern Africa has been pivotal to the development of infrastructure and the establishment of manufacturing industries and tertiary industries, while the importance of manufacturing industries based on a wide variety of minerals has grown substantially. The mining industry and the population centres that grew around it presented market opportunities for commercial agriculture and created domestic markets that encouraged the growth of industries to replace imports, such as robust local industries in the heavy engineering equipment and services, industrial chemicals and timber sectors that was facilitated by the industry's requirements. Railways, electricity and water reticulation, and secondary and service industries grew and matured on the back of this demand, resulting in the development of a modern, diversified industrial economy that has provided the foundation for future growth in the region (Chamber of Mines of South Africa, 2002:2-4).

The South African mining industry has also stimulated the development of local technology providers that are now serving the global mining industry. Similarly, local providers of knowledge-based mining services, such as mining consultancies and specialist mining contractors, have captured a share of the global market. The development of these industries represents the conversion of mineral endowment into lasting intellectual capital, which has the potential to benefit society over the long term (Chamber of Mines of South Africa, 2002:4).

Mining has also been a major contributor to the South African economy. For many years, the export of primary minerals from South Africa has accounted for the largest portion of total foreign exchange earnings. In terms of gross domestic product (GDP), mining (with gold mining as the most valuable component) remained the sector producing the largest share of South Africa's wealth until the 1960's, when it was overtaken by manufacturing. Currently, South Africa's mining industry contributes approximately 8% to South Africa's GDP and 50% of export earnings, increasing to 66% when processed mineral products are included. The industry also contributes approximately 1,8% of total state revenue and 10.1 per cent of domestic fixed investment, while the industry remains an important job provider

for large numbers of workers, despite the steady decline in number of workers, from approximately 550 000 workers in 1996 to 410 000 in 2000. Salaries and wages paid to mine employees totalled R24.5 billion in 2001. A similar profile is seen in the economies of most Southern African countries where millions of people depend on mining and its associated industries for their livelihoods (Mbendi, 1997; Chamber of Mines of South Africa, 2002:3, 4; Darrol, 2002b:157).

South Africa is the world's leading gold producer, providing nearly 15 per cent of all newly mined gold in 2001 and playing a pivotal role in the economic development of South Africa. Gold remained the country's major export and the greatest earner of foreign currency until 2001 and accounted for over 70 per cent of South Africa's export for most of the 20<sup>th</sup> century. Although declining from more than 50 percent in 1983, it still earned about 20 percent of South Africa's foreign exchange in 1996. The importance of these earnings has been enhanced by the incomes terms-of-trade multiplier effect. While being a very high net generator of foreign exchange, gold mining is also a very low net user of foreign exchange. Much of the material used in gold mining is acquired from the domestic economy (Main, 1996:9; Mbendi, 1997; Chamber of Mines of South Africa, 1998; Chamber of Mines of South Africa, 2002:3, 4; MMSD project, 2002a:102).

In the domestic economy, the relative importance of gold mining has fluctuated over the last decade with the performance of the gold price. Gold contributed 4,8 percent in broad macroeconomic terms to the GDP in 1995, which is substantially down from the 17 percent direct contribution recorded in 1980 when the gold price peaked. Taking into consideration the indirect contribution to the economy and the multiplier effects, gold mining's total contribution to GDP is closer to 10 percent (Main, 1996:7-8; Chamber of Mines of South Africa, 1998).

The gold mining industry also contributes substantially to the national fiscus, both directly and indirectly. The estimated total direct taxation paid by gold mining for the 1994/95 fiscal year was R1.5 billion. In considering the total contribution of gold mining to the national fiscus in terms of taxation, multiplier effects also have to be included. These include taxes paid by companies that supply or use mining products, by individuals who earn their primary incomes from gold mining, as well as indirect taxes paid by the gold mining industry (such as tax on fuel) (Main, 1996:8; Chamber of Mines of South Africa, 1998).

Although employment levels have been declining steadily since 1987, gold mining remains an important provider of jobs. The sector employed some 350 000 workers in 1995, representing approximately 2.3 percent of the total economically active population or 3.5 percent of all those formally employed in the economy. Approximately R8.8 billion was paid to these mine workers as wages. Estimates of the employment multiplier for the gold mining

industry indicate that for every three people employed on a mine, another one person is employed by industries, which serve the mining industry, both directly and indirectly. It is also estimated that every worker in the gold mining industry has between seven and ten dependants, thereby highlighting the social importance of the industry (Main, 1996:13; Chamber of Mines of South Africa, 1998; MMSD Project, 2002a:102).

Surrounding countries, such as Lesotho and Mozambique, also derive substantial benefits in the form of foreign exchange earnings and the employment of their nationals, through the repatriation of part of the employee's earnings. Between them, these countries supply some 40 per cent of the migrant labour force employed in South African gold mines. It is estimated that the portion of mineworker's earnings remitted to Lesotho account for some 60 per cent of that country's GDP (Main, 1996:14; Chamber of Mines of South Africa, 1998).

The mining industry is going through a period of profound change. In recent years South Africa's gold mining industry has started to encounter problems and it's major challenge is to remain profitable and competitive. Both the tonnage and the grade of ore have declined with time by as much as 60%, resulting in the share of free gold mined by South Africa dropping from 79% in 1971 to 31% in 1994 due to output being halved. Furthermore, costs have increased significantly due among others to the fact that the gold is several kilometres deep, while labour costs have also risen sharply, accounting for half the cost of running the mines. Companies have also been required to improve safety standards following twelve major accidents in twelve years and to improve the living conditions of employees. Lastly, the gold price has dropped significantly since 1989, making many mines marginal and forcing the closure of less profitable areas (Mbendi 1997; MMSD Project, 2002a:102).

The net result is that mining is increasingly becoming less competitive and must make radical changes if it is to attract additional investment, remain profitable and continue to provide employment. This has resulted in substantial restructuring of the industry, involving the merging of contiguous mines and the restructuring of the mining companies. It has also resulted in massive cuts in employment. Employment has fallen drastically over the past decade, accounting for just two per cent of the registered South African labour force in 2002. These changes in operations and the falling exchange rate have kept many South African producers competitive (Mbendi 1997; MMSD Project, 2002a:102).

Despite this, gold mining continues to play a vital role in the economic development of the country in terms of contributions to wealth creation, to employment and social upliftment of many workers and their families and to infrastructure development. In continuing to realise wealth, it will act as the support base for the development of other industries. The gold mining industry will also continue to play a substantial role in earning foreign exchange for South Africa, thus impacting on the current account of the balance of payments, on

monetary policy and on the general level of business activity in the country (Main, 1996:9; Chamber of Mines of South Africa, 1998).

However, few, if any economic activities, pose as great a threat to the environment in mineral rich South Africa as mining. While fuelling the economic growth of the country, mining activities also had negative social and environmental impacts within the communities and ecosystems in which mines operate. As a vital economic activity, that is entirely dependant on the winning of minute amounts of useful products from vast tonnage of ore extracted from the ground, mining will always contend with major environmental challenges. Mineral deposits are only potential sources of wealth, and the significance of deposits only become evident when the minerals are mined, resulting in the disturbance of the natural environment, while consuming a range of natural and other resources produce wealth from mined ores. Mining uses large quantities of water, energy and timber and is a single large contributor to the waste stream in South Africa. Although mining is viewed by some as a temporary land-use (though often for a lengthy period), the accompanying widespread conversion of natural habitats to urban, industrial and agricultural land uses is often permanent and may have wide-ranging effects, including urban sprawl, acid rain and pollution of rivers (Chamber of Mines of South Africa 1997:29; South Africa 1998:42; Chamber of Mines of South Africa, 2002:2, 10).

Therefore, the mining industry, by its very nature, has the potential to endanger human health and safety, as well as the physical environment. As mining impacts on the biophysical environment are inherent in the nature of the activity, the mining sector is under constant public pressure to demonstrate commitment to responsible environmental management (Chamber of Mines of South Africa 1997:29; South Africa 1998:42).

In an era of growing environmental awareness in South Africa, there is growing pressure on industry, including mines, to reduce their negative environmental impacts. Increasing pressure about environmental issues originates from a number of sources, such as international competitiveness, financial factors, legislative and regulatory compliance and enforcement, corporate image and reputation, interested and affected parties and growing environmental awareness. These pressures are more than a little threatening to the industrial sector and perhaps the greatest concern is that organisations will be forced into taking commercially unsound actions.

As concern grows for maintaining and improving the quality of the environment and protecting human health, organisations of all sizes are increasingly turning their attention to the potential environmental impacts of their activities, products or services. More and more companies are beginning to realise that business and industry will only survive if efforts are directed towards alleviating poverty and bringing patterns of production and consumption

into line with the ecological limits of the planet. An increasing number of organisations also realise that maintaining control of their business agenda requires maintaining control of their environmental agenda. By maintaining control over their environmental agenda, organisations are able to lower costs such as fines, penalties, insurance premiums, legal costs, remediation costs, and future liabilities. Most important, maintaining control over their environmental agenda allows organisations to increase shareholder value, because confidence in their future and public goodwill are important assets. At the same time, business is beginning to recognise environmental and sustainability issues less as threats (as has traditionally been the case) and more as sources of competitive advantage. This is also true for the mining industry (International Organization for Standardization, 1996b:v; Darrol, 2002a:19).

Not all environmental problems need to be solved by installing expensive equipment. Potentially significant environmental improvements (and cost savings) can be achieved by reviewing and improving an organisation's management processes. The key to effective environmental management is the use of a systematic approach to plan, control and improve an organisation's environmental efforts. Through the implementation of an effective environmental management system (EMS), organisations can maintain control over their environmental agenda (Stapleton *et al.* 1996:4).

An EMS is a structured approach to managing an environmental programme. It is defined as "the part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy" (International Organization for Standardization, 1996a:2). An EMS can be viewed as an organising framework that provides organisations to address environmental concerns in an orderly and consistent manner through the setting of objectives and targets, allocation of resources, assignment of responsibilities, ongoing evaluation of practices, procedures and processes and periodically reviewing progress towards meeting the targets. It consists of a repetitive cycle, with each stage being continuously revisited and improved on each visit. It provides a structured method for organisation management, ensuring that nothing is overlooked, tasks are carried out and checked, provision is made for changes and response procedures are established for emergencies. Such a system allows organisations to anticipate and meet their environmental objectives and to ensure ongoing compliance with national and/or international requirements (EPA, 1995:2; International Organization for Standardization, 1996b:iii; MMSD Project, 2002b:248).

The international ISO 14001:1996 EMS standard has been designed to help an organisation implement or improve its EMS. It defines the key elements of a management system that will help an organisation to address the environmental issues it faces. It challenges

organisations to take stock of their environmental aspects, establish their own objectives and targets, commit themselves to effective and reliable processes and continual improvement, and bring all employees and managers into a system of shared and enlightened responsibility for the environmental performance of the organisation. It also provides a framework for directing the use of organisational resources to the full breadth of actual and potential environmental impacts through reliable management processes and a base of educated and committed employees. The standard is therefore concerned with establishing "how to" achieve a goal, not "what" the goal should be. The expected outcome of this approach is continual improvement in environmental management. By providing a common basis for defining an appropriate EMS for many kinds of organisations, ISO14001 provides a context within which an organisation's claims about its environmental performance can be assessed (Cascio *et al.* 1996:ix, 37; International Institute for Sustainable Development, 1996:1,7; Von Zharen, 1996:15; Martin, 1998:9).

Mining companies have taken great strides over the last few decades in improving their environmental expertise. Environmental management has matured, from a haphazard process of site-based, narrow-focussed responses to individual environmental challenges, to an integrated programme providing a systematic approach to environmental protection and rehabilitation, and offering the means to test the results and strive for best practice. However, it is only recently that real attention has been given to a systematic approach to environmental management. Whilst private sector companies, especially in the chemical industry, have been particularly active in implementing international standards for environmental management, the mining industry has only become more active in considering environmental management systems to help drive improvement in environmental performance during the late 1990s. Progressive mining companies realise that the implementation of an EMS is now seen more broadly as a lever of corporate positioning that may drive broader business advantage in the global market place. At the same time, however, it is recognised that it is not the system alone that can help deliver such outcomes and support improved environmental performance. The full benefits of implementing an EMS will only be realised where there is senior management commitment and ongoing appropriate resource provisions to meet the changing requirements of the business (EPA 1995:2; Emery & Leiner, 1999:13).

In essence, the elements of the ISO 14001:1996 EMS are shaped and implemented around the organisation's environmental aspects and (potential or actual) environmental impacts. An organisation with no existing environmental management system should, initially, establish its current position with regard to the environment by means of a review process called the initial environmental review (IR) process. The aim should be to consider all environmental aspects (mechanisms that cause environmental impacts) of the organisation

as a basis for establishing the environmental management system (Cascio *et al.* 1996:108; International Organization for Standardization, 1996a:7; International Organization for Standardization, 1996b:5).

To date only a small percentage of gold mines in South Africa has implemented an EMS. The question of what significant environmental aspects need to be included in an initial review of a gold mine shaft business unit, therefore, largely remains unanswered. This study endeavoured to provide answers to this question and develop a generic model for the initial review process of a deep level gold mine shaft in terms of developing a generic scope for and identifying generic environmental impacts and aspects that need to be addressed by an EMS. The development of such a model should facilitate the development and implementation of an EMS at such shafts, thereby contributing to reducing the environmental impact of gold mines. The following key questions has been addressed:

- What are the boundaries of a typical deep level gold mine shafts in terms of its processes, activities, organisational structure and specific site conditions?
- What elements should form part of a generic scope for a deep level gold mine shaft as an essential part of a generic model for the ISO 14001 initial review process at such a shaft?
- What are the significant environmental impacts and aspects of deep level gold mine shafts?
- What are the business activities that could result in significant environmental aspects at deep level gold mine shafts?
- What generic aspects should be considered in a generic model for the initial environmental review process at a gold mine shaft?

The remainder of this dissertation consists of two articles, reflecting the research methodology followed and the results of the study. The first article addresses the development of a generic sub-model for determining the scope of a deep level gold mine shaft in South Africa in terms of business processes, physical boundaries and the staff component, as a first step towards developing a generic model for the initial review process. The second article focuses on the identification of significant environmental impacts and aspects, as well as generic business activities that are potentially destructive and carry a high risk of causing significant negative environmental impacts, in an attempt to further develop a generic model for the initial review process. The last chapter of the dissertation contains general conclusions. References are not listed at the back of the dissertation, but where relevant in the dissertation.

## References

- AUSTRALIA. Environment Protection Agency. 1995. Environmental management systems. Best practice environmental management in mining. Commonwealth of Australia. 40 p.
- CASCIO, J., WOODSIDE, G. & MITCHELL, P. 1996. ISO 14000 Guide. The new International Environmental Management Standards. New York: McGraw-Hill.
- CHAMBER OF MINES OF SOUTH AFRICA. 1997. Chapter 2: Environment and natural resources management - Annual report for 1996/97. Johannesburg: Chamber of Mines of South Africa. 82 p.
- CHAMBER OF MINES OF SOUTH AFRICA. 1998. The importance of gold mining to South Africa. [Available on Internet:] <http://www.bullion.org.za/bulza/educatn/nbgold98.htm> [Date of use: 16 Mar 1999]
- CHAMBER OF MINES OF SOUTH AFRICA. 2002. The contribution of the mining and minerals industry to sustainable development in South Africa. Johannesburg: Chamber of Mines of South Africa. 12 p.
- DARROL, L. 2002a. Indexing sustainability in South African business. Business & sustainable development. Johannesburg World Summit on Sustainable Development special edition. Sustainable Development International & Urban Green File joint venture publication. Johannesburg: Brooke Patrick Publications (Pty) Ltd.
- DARROL, L. 2002b. Sustainability in the mining sector. Business & sustainable development. Johannesburg World Summit on Sustainable Development special edition. Sustainable Development International & Urban Green File joint venture publication. Johannesburg: Brooke Patrick Publications (Pty) Ltd.
- EMERY, A. & LEINER, C. 1999. Overview of environmental management approaches and systems in the private sector (Condensed version). In: Carl Duisberg Gesellschaft e.V. Report on the international round table on mining and the environment held in Berlin from 22-26 November. Berlin: Carl Duisberg Gesellschaft e.V. p.13-17.
- EPA. See AUSTRALIA. Environment Protection Agency.
- INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT. Global green standards: ISO 14000 and sustainable development. Winnipeg, Manitoba. 95 p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996a. Environmental management systems - Specification with guidance for use. South African Standard. SABS ISO 14001:1996. South African Bureau of Standards. 14p.

- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996b. Environmental management systems - General guidelines on principles, systems and supporting techniques: South African Standard. SABS ISO 14004:1996. South African Bureau of Standards. 31 p.
- MAIN, T.R.N. 1996. Address of the Chief Executive, South African Chamber of Mines at the World Gold Conference. Venice, 24-25 June.
- MARTIN, R. 1998. ISO 14001 Guidance Manual. Technical report NCEDR/98-06. National Centre for Environmental Decision-making Research. University of Tennessee. 95 p.
- MBENDI. 1997. South Africa - Mining industry profile. 27 Nov. 1997. [Available on Internet:] <http://www.mbendi.co.za/indy/ming/mingsa.html> [Date of use: 16 Mar. 1999]
- MMSD PROJECT. See MINING, MINERALS & SUSTAINABLE DEVELOPMENT PROJECT.
- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002a. Case studies on minerals. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. 86-110.
- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002b. Mining, minerals and the environment. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. 231-267.
- SOUTH AFRICA. Department of Minerals and Energy. 1998. White paper on a Minerals and mining Policy for South Africa. Pretoria. 67p.
- STAPLETON, P.J., COONEY, A.M. & HIX, W.M. 1996. Environmental management systems: An implementation guide for small and medium-sized organisations. NSF International. Michigan: Ann Arbor. 160 p.
- VERSTER, J.J. & VAN LUITINGH, P. 1997. SA's mineral role within the SADC. Mining magazine, 177(1):48, Jul.
- VON ZHAREN, W.M. 1996. ISO 14000: understanding the environmental standards. Rockville: Government Institutes Inc. 206 p.
- WELLS, J.D., VAN MEURS, L.H. & RABIE, M.A. 1992. Terrestrial minerals. (In Fuggle, R.F & Rabie, M.A., eds. Environmental management in South Africa. Cape Town: Juta & Co, Ltd. p. 337-379.

## **Chapter 2**

### **Implementing Environmental Management Systems to improve sustainable development in gold mining:**

#### **1. Towards a generic scope for deep level gold mine shafts in South Africa.**

TC Meyer <sup>(1)</sup>

(1) Centre for Environmental Management, Potchefstroom University

#### **Abstract**

South Africa is one of the world's foremost and most diverse mining and mineral processing nations and mining and its associated industries continue to form the cornerstone of the economies of most southern African countries. Mineral resources hold the promise of long-term social and economic benefits for the region, which are recognised as a key component of the New Partnership for Africa's Development (NEPAD).

However, few, if any, economic activities pose as great a threat to the environment as mining. The mining industry has, by its very nature, the potential to endanger human health and safety, as well as the physical environment. As an activity that is dependent on the winning of minute amounts of useful products from vast tonnage of ore, mining will always contend with major environmental challenges and remain under constant public pressure to demonstrate commitment to responsible environmental management.

The key to effective environmental management is the use of a systematic approach to plan, control and improve environmental efforts. An Environmental Management System (EMS) employs such an approach and allows organisations to address environmental concerns in an orderly and consistent manner. It allows organisations to anticipate and meet their environmental objectives and to ensure ongoing compliance with national and/or international requirements.

Although a few gold mines in South Africa have implemented an EMS, the question of which significant environmental aspects need to be managed in such a system at a deep level gold mine shaft, remains largely unanswered. This paper is one of two that will endeavour to provide answers to this question and to develop a generic scope for the business processes, physical boundaries and personnel component of a deep level gold mine shaft. Such a model should facilitate the development and implementation of an EMS at such shafts in the gold mining industry.

The results of this study indicates that a generic scope can be developed to describe the business processes, physical boundaries and personnel component of a deep level gold mine shaft, as many common aspects were found between the two shafts studied. However, it also illustrated that there are certain non-generic issues at such shafts and sites that must be considered when determining the scope of any such shaft. The generic sub-model can be used to determine the scope of deep level gold mine shafts prior to the development of an EMS.

## **Uittreksel**

Suid-Afrika is een van die wêreld se voorste en mees diverse mynbou- en minerale prosesseringsnasies en die mynboubedryf is baie belangrik vir die land se ekonomie. Ten spyte van onlangse negatiewe ekonomiese neigings en druk op kommoditeitspryse, bly mynbou en die geassosieerde nywerhede die hoeksteen van die meeste suider Afrikaanse lande se ekonomieë. Minerale hulpbronne hou die belofte in van langtermyn sosiale en ekonomiese voordele vir die streek. Sulke potensiële voordele word erken as 'n sleutelkomponent van die Nuwe Vennootskap vir die Ontwikkeling van Afrika (NEPAD).

Baie min, indien enige, ekonomiese aktiwiteite hou egter so 'n groot bedreiging in vir die omgewing as mynbou. Die kern van mynbou-aktiwiteite, naamlik die onttrekking van baie klein hoeveelhede bruikbare produkte vanuit massiewe hoeveelhede erts, is potensieel skadelik vir mense se gesondheid en veiligheid, asook die omgewing. Daarom sal mynbou altyd gekonfronteer word deur groot omgewingsuitdagings en onder konstante druk verkeer om sy verbintenis tot verantwoordelike omgewingsbestuur te demonstreer.

Die toepassing van 'n sistematiese benadering tot beplanning, beheer en verbeterde bestuur is die sleutel tot doeltreffende omgewingsbestuur. 'n Omgewingsbestuurstelsel (OBS) gebruik so 'n benadering en stel organisasies in staat om hulle omgewingskwessies op 'n ordelike en konsekwente wyse aan te spreek. Dit stel organisasies ook in staat om hulle omgewingsdoelwitte te antisipeer en te bereik, asook om voortdurende nakoming van nasionale en internasionale vereistes te verseker.

Alhoewel 'n paar goudmyne in Suid-Afrika alreeds 'n OBS geïmplementeer het, bly die vraag oor watter betekenisvolle omgewingsaspekte in so 'n stelsel by 'n diep ondergrondse goudmynskag aangespreek moet word, grootliks onbeantwoord. Hierdie artikel is die eerste van twee waarin gepoog sal word om antwoorde op hierdie vraag te verskaf en 'n generiese model vir die basislyn-opnameproses (initial review process) vir 'n diep ondergrondse goudmynskag te ontwikkel. So 'n model kan die ontwikkeling en implementering van 'n OBS by sulke skagte in die goudmynbedryf 'n hupstoot gee.

Die resultate van hierdie studie toon aan dat 'n generiese sub-model ontwikkel kan word om die bestek/omvang van 'n diep ondergrondse goudmynskag te beskryf in terme van die besigheidsprosesse, fisiese grense en personeelkomponent daarvan, aangesien baie gemeenskaplike aspekte gevind is tussen die twee skagte wat bestudeer is. Die studieresultate het egter ook aangetoon dat daar sekere nie-generiese aspekte by sulke skagte en terreine is wat oorweeg moet word wanneer die omvang daarvan bepaal word. Die generiese sub-model kan gebruik word om die bestek van diep ondergrondse goudmynskagte te bepaal voor die ontwikkeling van 'n OBS.

## **1. Introduction**

South Africa is one of the world's foremost and most diverse mining and mineral processing nations. The highly mineralised nature of many parts of South Africa has led to the creation

of a mining industry, which is very important to the country's economy (Wells *et al.* 1992:362; Verster & Van Luitingh, 1997; Mbendi, 1997; Chamber of Mines of South Africa, 2002:2). Despite recent adverse economic features and depressed commodity prices for many metals and mineral products, mining and its associated industries continue to form the cornerstone of the economies of most southern African countries (MMSD Southern Africa, 2002:12). Mineral resources hold the promise of long-term social and economic benefits for the region, which are recognised as a key component of the New Partnership for Africa's Development (NEPAD). Responsible mining can also contribute to the region's move towards sustainable development (MMSD Southern Africa, 2002:5).

However, few, if any, economic activities pose as great a threat to the environment as mining that is dependent on the winning of minute amounts of useful products from vast tonnage of ore and by its very nature, has the potential to endanger human health and safety, as well as the physical environment. Consequently, the mining industry will always contend with major environmental challenges and remain under constant public pressure to demonstrate commitment to responsible environmental management (Chamber of Mines of South Africa 1997:29; South Africa 1998:42; Chamber of Mines of South Africa, 2002:2).

The key to effective environmental management is the use of a systematic approach to plan, control and improve environmental efforts. Potentially significant environmental improvements can be achieved by improving an organisation's management processes (Stapleton *et al.* 1996:4). Although a few gold mines in South Africa have implemented an EMS, there is still some uncertainty about which significant environmental aspects need to be managed in an EMS at deep level gold mine shafts.

This paper will endeavour to provide some answers to this question, by exploring the possibility of developing a generic scope for deep level gold mine shafts in South Africa, as essential part of a generic model for the ISO 14001 initial review process at such shafts. Such a model could facilitate the development and implementation of an EMS at deep level shafts in the gold mining industry. The following key questions will be addressed:

- What are the boundaries of a typical deep level gold mine shafts in terms of its processes, activities, organisational structure and specific site conditions?
- Which elements should form part of a generic scope for a deep level gold mine shaft as an essential part of a generic model for the ISO 14001 initial review process at such a shaft?

## **2. Study area**

The study was undertaken at two gold mine shaft business units of the world's largest gold producer and holder of the most substantial gold reserves. Both are deep level operations in the vicinity of Orkney in South Africa, extracting gold from placer deposits, mining at an average depth of 2100 metres below surface. In order to account for the possible impact that the time of initial development of the shaft, as well as the age and stage in the mining life-cycle could have on the scope of a deep level gold mine shaft, the two shafts differ distinctly in respect of these parameters.

Shaft A commenced production in 1972. It is among the deepest shafts in South Africa, operating over eight main levels with an average depth of 2400m. This low-cost high-value shaft is currently operating at full capacity. It is expected that this will continue over the expected 15 remaining years of the mine's life, but yields are expected to decline and tonnage to drop in steps. Therefore, the focus at this shaft is on maintaining its low-cost profile as grades drop.

Shaft B is located adjacent to shaft A and is still being developed to exploit a mineral resource that lies between 2,100 m and 3,700 m below surface. The plan is to establish a modern mine through implementation of the latest technology. Development at the shaft started in 1991, while the main shaft was commissioned in 1998 and by the end of 2000 had been sunk and equipped to a depth of 2.400 m. The development of the infrastructure is under way through the temporarily equipped rock ventilation shaft and will continue for several years to come. Currently, the trackless method of development is employed. This modern shaft is economic to run and is expected to reach full production by 2008.

The empirical part of the study was conducted over the period November 1999 to August 2000 and the information regarding the scope of the shaft business units were valid at the time of the study. Due to changing circumstances and conditions at these shafts, it is possible that the information on the scope of the specific shaft business units might have changed since then. However, the aim of the study was not to evaluate the actual situation at a specific shaft on any specific moment, but rather to develop a generic scope for deep level gold mine shafts. As such, the outcomes of the study are still considered to be valid.

## **3. Research methods**

### **3.1. The initial review process.**

ISO 14001:1996 (sub-clause 4.3.1) requires organisations to establish procedures for identifying significant environmental aspects that should be addressed as a priority by the

organisation's environmental management system (EMS). The process of identifying all environmental aspects, impacts, risks and problems is possibly the most taxing and time consuming part of developing an EMS. An organisation with no existing environmental management system should, initially, establish its current position with regard to the environment by means of a review. However, organisations with operating environmental management systems do not have to undertake such a review (International Organization for Standardization, 1996a:7).

The initial review is a fact-finding review of the whole organisation intended to establish a benchmark on an organisation's environmental performance. To ensure that the environmental aspects of the organisation are assessed as a basis for establishing the EMS, the initial review process should consider all inputs and outputs associated with the activities, products and processes of an organisation (Gilbert, 1993: 62, 118; International Organization for Standardization, 1996a:7). This process can be equated to an environmental impact assessment (EIA) that should reveal the potential environmental impacts of a mine during its lifetime. As the vital first stage element in devising strategies to control these effects and managing the environment on a site, it is the foundation of the EMS. The findings should form the initial objectives, targets and procedures that an organisation must achieve or implement (EPA, 1995:4, 16).

The International Organization for Standardization (1996a:7) states that the initial review should cover four key areas. These areas, as expanded on by Kuhre (1995:67); Gilbert (1993: 68) and the International Organization for Standardization (1996b:5) are summarised in Table 1.

Other areas that might also be considered during the initial review include community perceptions of the organisation's environmental aspects and activities; customer perceptions of the environmental characteristics of the organisation's products and services, existing processes, documentation, work practices and opportunities for competitive advantage. Functions or activities of other existing organisational systems, such as quality systems already in place, that can enable or impede environmental performance; opportunities for technology sharing, joint ventures, and strategic alliances to obtain a competitive advantage, might also be considered (Gilbert, 1993: 62-63; International Organization for Standardization, 1996b:5).

**Table 1:** Key areas to be covered by the initial review, with types of information to be considered.

<b>Key area #1</b>	<p><b>Identification and evaluation of applicable legislation and regulatory requirements</b></p> <p>Consider existing policies and programmes, the organisation's current performance with regard to relevant internal criteria, external standards, regulations, codes of</p>
--------------------	---

	practice, as well as sets of principles and guidelines.	
Type of information to consider	Current legal obligations and consents Future regulations Communication with regulators	Product legislation Marketplace legislation Waste controls
<b>Key area #2</b>	<b>Identification and evaluation of environmental aspects/ processes/ products/risk areas</b> Consider all activities, products or services of organisations in order to determine those that have or can have significant environmental impacts and liabilities.	
Type of information to consider	Raw material sources Suppliers performance Transport and distribution Water quality and use Energy management and use Types and volumes of waste Waste storage and disposal methods Recycling or reuse status	Duty of care compliance Discharges Heat, light and power Product design Packaging Consumer management BATNEEC analysis BEO analysis
<b>Key area #3</b>	<b>Examination of all existing environmental management practices and procedures</b>	
Type of information to consider	Environmental policy Environmental strategy Environmental responsibilities Materials and equipment supplies Products assessments Procurement policy Procurement practices and procedures Contracting practices and procedures Insurance and indemnities	Investment plans Project assessments Training and skills base Environmental records Environmental audits Environmental reporting Environmental reviews Communications Public relations
<b>Key area #4</b>	<b>Evaluation of feedback from previous accidents or failures</b>	
Type of information to consider	Non-compliance records Incident and accident records Emergency response training Emergency planning	Contingency plans Progress or action plans Communication strategy

The process is intended to identify significant environmental aspects associated with activities, products, or services, and not to require a detailed life cycle assessment. Organizations do not have to evaluate each product, component or raw material input. They may select categories of activities, products or services to identify those aspects most likely to have a significant impact (International Organization for Standardization, 1996a:7).

### 3.2. Determining the scope of deep level gold mine shafts

An EMS is developed and implemented for an organisation, which is defined as a “company, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration.” (International Organization for Standardization:1996:2). Delineating the scope of the

organisation is an important first step in the EMS planning process, as this puts a boundary not only around the EMS, but also around the initial review assessment. It is important to decide what areas and activities will be covered and what not (Global Environmental Management Initiative, 1996:3; International Organization for Standardization, 1996b:5; West & Manta, 1996:9).

Organisations have the freedom and flexibility to define the boundaries of their systems, which may include specific organisational activities, specific operations or a specific site. They may choose to implement an EMS throughout the entire organisation, or within specific operating units or activities of the organisation. If the definition of the organisation is limited to a typical plant operation, environmental aspects could be limited to the effects of the plant operations and activities in the vicinity of the plant. If the definition of the organisation is broader, required procedures could for example include raw material specification and procurement practices, process and equipment design and re-design, and product design and re-design. In larger organisations, primary responsibility for these activities is placed outside the plant organisation (International Organization for Standardization, 1996b:5; West & Manta, 1996:9).

When defining the scope of the organisation, it is essential to give consideration to business priorities, i.e. which part of the business must be the focus of the review, what are the expectations at the completion of the project, what are the time constraints and what resources are available? The level of detail and complexity of the initial review will depend on many things. Location, nature and complexity of operations, level and number of environmental impacts and specific operating conditions are a few variables that will determine the depth needed. If an organisation has many impacts on the environment, it will need a much more in-depth system than an organisation with little impact. In addition to impact, the number of employees in the organisation will also suggest a reasonable level of effort or depth (Kuhre, 1995:21; Global Environmental Management Initiative, 1996:3; International Organization for Standardization, 1996b:5; West & Manta, 1996:9).

According to Nel (2002), the scope of an organisation should focus on three aspects specific to the organisation, i.e. business and/or production processes, a site with geographical boundaries, as well as organisational (personnel) structure. It is important to identify the business and/or production processes involved to allow for consideration of the nature of the functional, logistical and supporting processes, the nature and extent of environmental impacts due to the raw materials used and products produced, the nature and extent of waste and/or pollutants generated, as well as the age and performance capabilities of the existing technologies. Demarcating the geographical boundaries of the site assists in focussing on what enters and leaves the defined area, especially in terms of storm water and effluent, waste and other forms of pollution. Considering the organisation's organogram

assists in ensuring that everybody included in the scope of the organisation operate within the geographical boundaries and/or processes identified.

The two deep level gold mine shafts, which were the focus of this study, conformed to the ISO 14001 definition of an organisation. The scope of the organisations included all activities, products and services that were managed by the respective mine managers. As a result: -

- the business processes focussed on the core activity of extracting gold ore, as well as the administrative and other supporting functions; while
- the geographical boundaries of the organisations coincided with the geographical areas of responsibilities of the two shafts;
- all personnel operating within the geographical boundaries and involved in the scoped in business processes were included in the scope of the organisations.

**3.2.1. Identifying the geographical boundaries, business processes and organisational structures of deep level gold mine shafts**

ISO 14015 provides guidance on how to conduct environmental assessments of sites and organizations (EASO) through a systematic process of objectively identifying and evaluating environmental issues/aspects associated with sites and activities, as a result of past and current activities (Table 2). A site is defined as a “location with geographical boundaries that are defined and on which activities under the control of an organization may be carried out” (International Organization for Standardization, 2001:v).

**Table 2:** Basic steps of the EASO process (International Organization for Standardization, 2001: 2).

<b>Step</b>	<b>Activities</b>
Plan the assessment	Define objectives, determine scope, determine assessment criteria, develop the assessment plan
Gather & validate information and data	Review existing documentation and records, observe activities and physical conditions, and interview relevant personnel
Evaluate information & data	Validate all information and data to identify and evaluate environmental issues
Report on findings of the assessment	

The EASO process formed the basis of the initial review scoping process followed in this study.

### **3.2.1.1. Scoping (assessment) plan**

The objective of the scoping assessment was to identify, gather and evaluate information on the geographical boundaries, business processes and organisational structures of the deep level gold mine shafts.

### **3.2.1.2. Collecting, validating and evaluating the information and data on environmental impacts and aspects**

Various complementary methods were used to collect and validate the required information. The identification of business processes, geographical site boundaries and organisational structures of shafts is based on validated information on these aspects, gathered during the scoping process. This was done through reviewing existing documents and records (both prior to and during site visits), observing activities and physical conditions on site and interviewing mine personnel and contractors. Care was taken to ensure that sufficient, relevant and accurate information and data were collected, recorded and used in establishing the scope of the shafts.

- **Survey of available documents and records**

Various documents were obtained from the organisation. The documents that proved the most valuable included the approved Environmental Management Programme Report and draft water use application for the parent organisation, as well as site maps, current permits and letters. All the documents were reviewed to obtain a sufficient understanding of the site and the organisation. Relevant information was extracted and used to compile checklists and questionnaires of all the areas that needed to be reviewed during the site visit and interviews. These checklists formed the basis for the interviews and site visit.

- **Interviews**

Employees at all levels proved to be a most valuable source of information. Interviews with individual employees prior to, during and after the site visits, formed an essential part of the initial review. These interviews were conducted with the approval of the client organisations. Interviews were also conducted with contractors and personnel from neighbouring organisations, such as the metallurgical plant.

Interviews were used to gather more detailed information on the geographical boundaries, business processes and organisational structures of shafts. The checklists and questionnaires developed during the document review process were used as a basis for the interviews to ensure that the activities of the shafts were covered in detail. Apart from being relatively quick, cheap to implement and easy to use, it also had the advantage of being flexible, allowing for updating during the scoping process, as experience and information were gathered. Information gathered was used to

corroborate or augment information from the review of existing documents, as well as from observations made during the site inspections.

- **Site inspections**

Site visits were used to confirm the physical boundaries of the sites, the limits of the operations, areas of responsibility, as well as the business processes of the shafts. The information gathered was also used to corroborate or augment information from the document reviews, as well as from claims made during the interviews.

### **3.2.2. Business process analysis**

A good understanding of the processes by which products and services are generated is essential for understanding the environmental aspects of an organisation. A process consists of any activity or set of interrelated or interacting activities that uses resources to transform inputs to outputs (International Organization for Standardization, 2000:2).

Any business process can be analysed by understanding the various process steps as activities that have an input, added value and output. A flow chart of the major processes may help to understand the inputs and outputs of the processes, how materials are used and what wastes are created, but the extent of the process being assessed must be defined (Gilbert, 1993:125; Stapleton *et al.* 1996:17).

Business maps are ideal tools for doing business process analysis in order to improve the understanding of a business. Business maps visually depict the system of relationships and processes within and around organisations. Used effectively, they generate a common understanding of these processes and relationships. There are many different types of business maps, but process relationship maps and process maps have proven particularly useful in improving organisational performance.

A process relationship map represents a high-level view of an organisation. It graphically depicts the relationships between the processes used by the organisation as it seeks to deliver its products and/or services to customers. Such a map shows, through inputs and outputs, how each process interacts with other processes. It describes the way work is accomplished and literally maps out the sequential steps involved in converting a specific input into a specific output.

## 4. Results

### 4.1. Scope of Shaft A

#### 4.1.1. Business processes

The core function of Shaft A is to extract and deliver gold ore to the gold and uranium metallurgical plants. Planning, development and maintenance activities support the core mining activities. Planning of new mining areas to be developed, of the shaft sinking and development operations to access and extract the mineral deposits, as well as of the maintenance that may be required, is followed by the development and maintenance of the required infrastructure and service networks.

Logistical activities related to the core mining function include transporting people, equipment and material to and from the underground working areas, preparing and blasting the ore bodies, clearing the blasted areas and transporting gold ore to the metallurgical plants, while the waste rock is dumped on the waste rock dump. A range of administrative functions also needs to be performed to allow all of the above activities to continue unabatedly.

#### 4.1.2. Site description

The site of Shaft A business unit covers the surface area surrounding the shaft. It is a fairly old site with some facilities that are no longer used, while upgrading and redevelopment is taking place on a wide scale. The site includes various facilities, related to the abovementioned business processes (Table 3).

**Table 3:** Facilities found on the site of Shaft A and their relations to the core mining and operational support, as well as logistical and administrative supporting functions.

<b>Core mining and operational support processes</b>	<b>Development and maintenance (logistical) support processes</b>	<b>Administrative support processes</b>
Operations control centre	Car ports	Main offices
Main shaft	Canteen	Temporary offices
Up cast shaft	Rescue room	Boart temporary offices
Winder house	Electrical workshop	Logistics offices
Change house	Horizontal transport workshop	IMS store
Surface bank area	Pump repair workshop	Capital store
Surface cooling towers	Surface boiler workshops	Vertical transport store
Surface fridge plant	Raise boring workshop	Rock drill & drill steel store

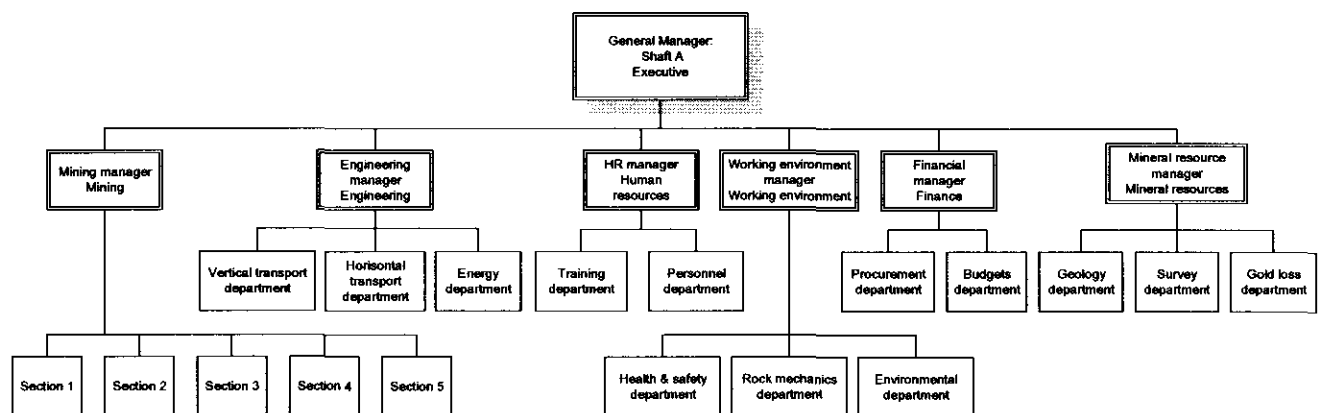
Compressor house & cooling tower	Salvage/reclamation store	Timber yard & vehicle stores
Ventilation fans	Ex refrigeration workshop	Environmental store yard
Vertical transport offices	Sewage pump house	Domestic waste collection area
Explosives yard	Old pipe yard	Old oil storage areas
Overhead conveyor and reef bin	Old timber yard	Radio-active waste storage area
Waste rock dump	Old cable yard	Solid waste wash down & sorting area
Backfill plant	Cable yard	Solid waste temporary storage area
High quality waste dump	Compressor store yard	
Dirty water storage reservoir	Mining stores	
	Mining oil store	
	Underground tip steel storage area	
	Transformers	

#### 4.1.3. Organisational structure

The mine manager at Shaft A heads a personnel component organised into six management units, i.e. mining, engineering, mineral resources, working environment, human resources and finances. Each management unit is headed by a manager and consists of a number of departments, which are managed by a department head (Figure 1).

Due to the fragmented and poorly organised nature of the site, as a result of continued development and redevelopment, it was difficult to plot the different areas of responsibility on a map.

**Figure 1:** Organogram of Shaft A



## 4.2. Scope of Shaft B

### 4.2.1. Business processes

The current core function of Shaft B is to develop and equip a shaft system and infrastructure capable of supporting a modern mine to extract and deliver gold ore. The core development activities are supported by the planning of the shaft sinking, development and maintenance operations to access and extract the mineral deposits in new mining areas, as well as the maintenance of the required infrastructure and service networks. The core development activities are also supported by logistical activities such as the transport of people, equipment and material to and from the shaft and underground working areas, the preparation and blasting of the shaft and access tunnels, the clearing of the blasted areas and the transportation of the waste rock to the waste rock dump. A range of administrative functions is also performed to allow all of the above activities to continue.

Apart from the above, there is also a sewage treatment works located within the geographical boundaries of the shaft's area of responsibility, as well as a large area of natural veld surrounding the shaft.

### 4.2.2. Site description

The site covers the surface area surrounding the shaft, the area where the sewage treatment works and waste rock dump is situated, an area where initial shaft sinking operations started as well as a large portion of undeveloped, vacant land around the shaft. The site includes various facilities, normally associated with a deep level gold mine shaft (Table 4).

**Table 4:** Facilities found on the site Shaft B, related to the core development and operational support, as well as logistical and administrative supporting functions.

<b>Core development and operational support processes</b>	<b>Development and maintenance (logistical) support processes</b>	<b>Administrative support processes</b>
Main shaft	Electrical sub station	Main offices
Up cast shaft	Potable water reservoir	Temporary offices
Overhead walkway	Old shaft sinkers area	
Winder house	Old core yard	Taxi rank
Change house	Car ports	IMS store
Surface bank area	New workshop and steel yard	Oil store
Fridge plant & condenser towers	Old workshop	Stacking area & timber yard
Emergency shower behind fridge plant	Batch plant - surface infrastructure	Access control, community hall and entrance walkway

Compressor & cooling tower	Batch plant – underground infrastructure	Sewage works
Ablution facility next to compressor house		Scrap/radiation yard
Ventilation fans		Solid waste wash down area
Overhead conveyor and silo		Industrial solid waste
Waste rock dump		Borrow pits
		Old shaft sinkers dams
		Earth fills
		Polluted water dam

Due to the fact that the shaft is still being developed, all planning, development, mining and maintenance processes are primarily focussed on ensuring as ideal an operating environment as is possible once the shaft starts producing. Consequently, the site is well planned with limited signs of new developments and upgrading. The surface water management network consisting of hardened surfaces, drains, trenches, pipelines, sump with oil separator and a polluted water dam is a good example to illustrate the point. The site also has a well-developed storm water management infrastructure.

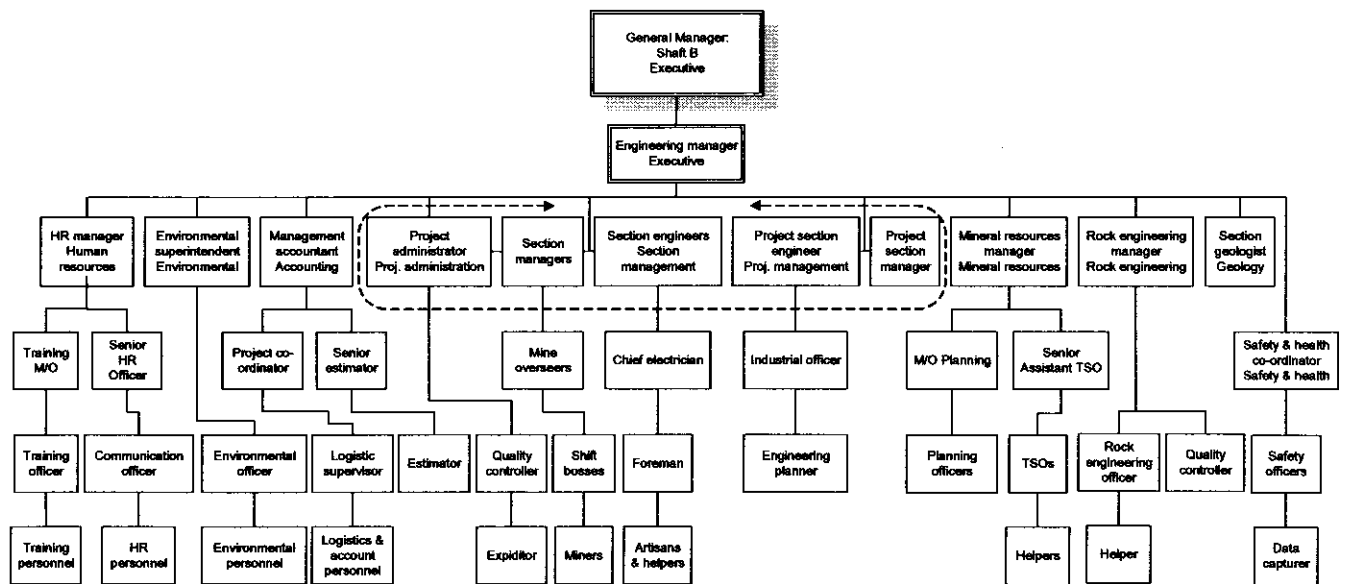
The fairly large area used by contractors during the early shaft sinking and development activities, primarily consists of disturbed and polluted land and old slimes dams that are being rehabilitated, as well as an area covered by redundant steel equipment.

#### **4.2.3. Organisational structure**

The personnel component at Shaft B consists of a general manager and an engineering manager, supported by the mining personnel and seven departments, i.e. mineral resources, rock engineering, geology, human resources, environmental, safety and health and accounting, each managed by a department head. The mining personnel consist of a project section manager and project section engineer for the development project, supported by a project administrator, as well as section managers and section engineers for each section. The personnel within the respective departments/sections all support the above structure.

Due to the well-planned and organised infrastructure at this shaft, it was fairly easy to indicate specific areas of responsibility on the site map.

**Figure 2: Organogram of Shaft B**



### 4.3. Towards a generic scope for a deep level gold mine shaft

According to the literature reviewed, a generic scope for a typical deep level gold mine shaft should address the boundaries thereof in terms of:

- the business processes and activities,
- the physical site with facilities and
- the organisational structure.

#### 4.3.1. Identifying generic business processes and activities at a deep level gold mine shaft

Based on the literature review, as well as the business processes and activities observed at the two case studies, five generic business processes were identified for deep level gold mine shafts, i.e. planning, development, mining (core & operational support), maintenance and administration (Figure 3).

Planning, both at strategic management and operational levels, is the first process to follow the confirmation of mineral resources that can be mined economically. This includes planning of new mining areas to be developed, including the necessary infrastructure and service networks in these areas; planning of the shaft sinking and development operations to access and extract the mineral deposits; as well as planning of the maintenance to the infrastructure and service networks that may be required. All of these planning activities are supported by accompanying budgets. Although these planning activities often run concurrently, they do not necessarily commence and end at the same time.

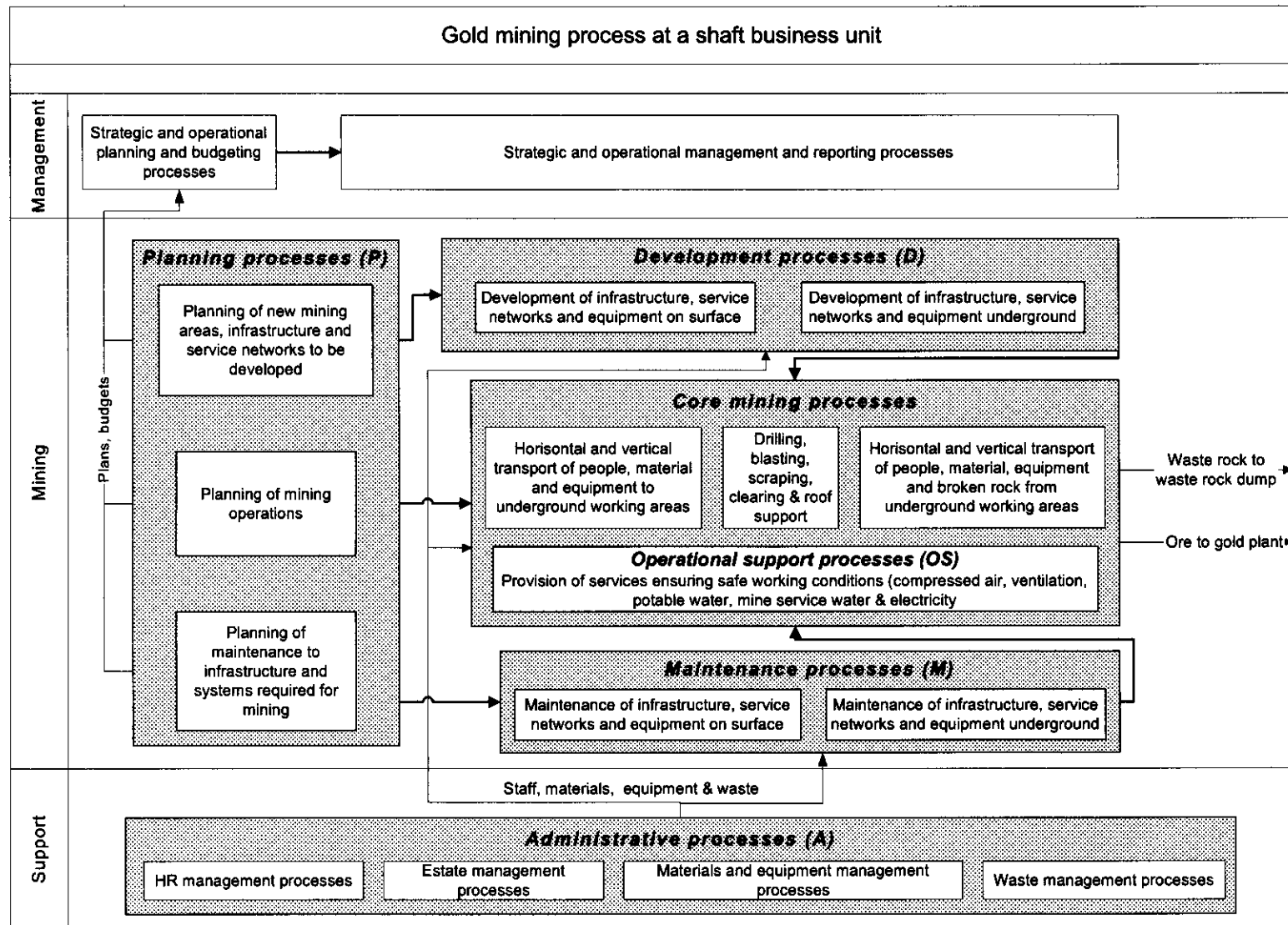
Planning of mining activities is followed by a number of processes to develop the infrastructure and service networks required to access the mineral deposits, both on the surface as well as underground. Surface infrastructure that needs to be developed includes facilities

such as the shaft headgear, winding house, change house, ventilation and refrigeration facilities and systems (including compressors, fans, cooling towers, refrigeration plants), offices, stores, store yards and workshops. Service networks that need to be developed on surface include systems for the provisioning of water (potable and service), electricity, compressed air, horizontal transport of equipment, materials, waste rock and ore, as well as for the removal and treatment of liquid and solid wastes (including surface runoff water).

Infrastructure that needs to be developed underground include facilities such as the main and ventilation shafts, vertical transport system in the main shaft, underground tunnels, haulage ways, emergency bays, ventilation and refrigeration facilities and systems (including compressors, fans, refrigeration plants), underground stores, and underground workshops. Service networks that need to be developed underground include systems for the provisioning of water (potable and service), electricity, lighting, compressed air, ventilation, cold air, horizontal transport of equipment, materials, as waste rock and ore, as well as for the removal and treatment of liquid and solid wastes.

Mining processes to extract the gold ore follow the development of the infrastructure and service networks required to access the mineral resources. These include core mining processes such as the transport of people, material and equipment to and from the underground working areas, drilling of holes for explosives, loading of explosives, blasting,

Figure 3: Generic business and production processes at a deep level gold mine shaft



scraping and clearing of rock, transport of broken rock (ore and waste) to the surface, as well as installation of roof support equipment. Apart from being used for the extraction of mineral deposits, these processes are also employed for the development of underground infrastructure. The mining processes are dependent upon the provision of a safe working environment through operational support processes such as the provision of potable water, mine service water, compressed air, ventilation and electricity.

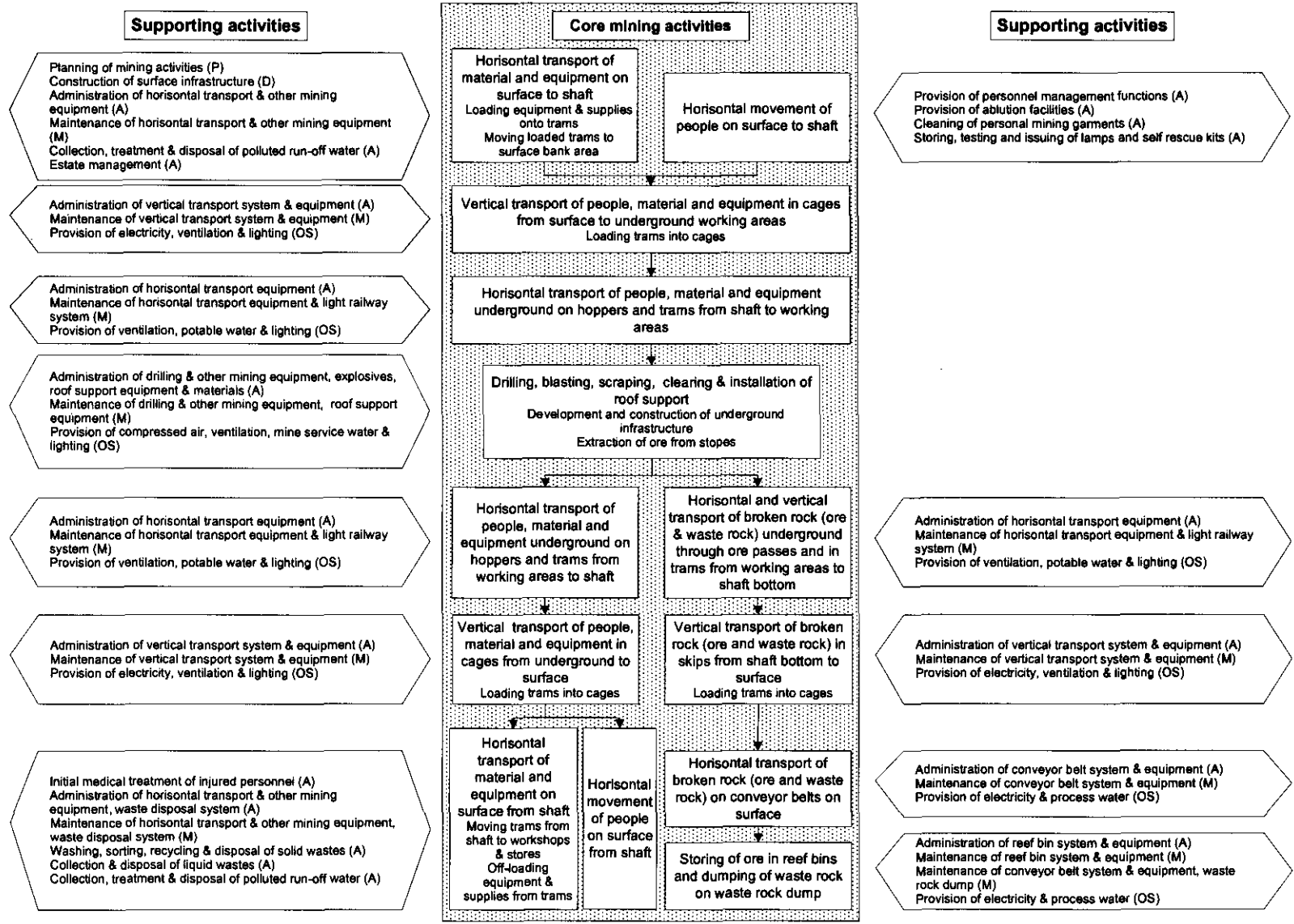
In order to allow the mining process to continue unabatedly, it is necessary to maintain all the infrastructure, service networks and equipment, both on surface as well as underground, but also to administrate all of the mentioned activities.

Based on the above discussion, specific activities were identified for the identified generic business processes (Figure 4). The activities directly related to the ore extraction process, are depicted as core mining activities, while the supporting activities are shown as planning (P), development (D), maintenance (M), administrative (A) and operational support (OS) activities. These activities were used as the basis for identifying 42 generic activities (Table 5).

#### **4.3.2. Identifying generic facilities at a deep level gold mine shaft.**

Based on the information about facilities at Shafts A and B, it was possible to identify a number of facilities, required to perform the generic business processes and activities, that seem to be generic to deep level gold mine shafts (Table 6).

**Figure 4: Activities at a deep level gold mine shaft related to the business and production processes.**



**P – Planning processes    D – Development processes    M – Maintenance processes    OS – Operational support processes    A – Administrative processes**

**Table 5: Generic activities related to the business processes at a deep level gold mine shaft**

<b>Core mining activities</b>	
1	Horizontal movement of people to and from shaft
2	Loading equipment and supplies onto trams and unloading
3	Horizontal transport of equipment, material and wastes to and from shaft on trams
4	Loading trams into cages
5	Vertical transport of people, equipment, material and wastes
6	Horizontal transport of people, equipment and material, wastes underground
7	Drilling holes in rock face
8	Preparation of explosives
9	Transporting explosives to underground workings
10	Loading of explosives into shot holes
11	Blasting rock
12	Scraping and clearing of blasted rock
13	Installation of roof support systems
14	Horizontal transport of broken rock (ore and waste rock)
15	Vertical transport of broken rock to surface
16	Horizontal transport of broken rock on surface
17	Storing of ore in reef bins
18	Dumping of waste rock on waste rock dump
<b>Operational support activities</b>	
19	Provision of compressed air
20	Provision of ventilation
21	Provision of potable water
22	Collection, settling, treatment, cooling and recycling of mine service water
23	Provision of electricity and lighting
<b>Administrative support activities</b>	
24	Provision of personnel management functions
25	Provision of food
26	Initial medical treatment of injured personnel
27	Administration of mining activities, materials, equipment and systems
28	Administration of waste disposal system
29	Washing, sorting, recycling and disposal of solid wastes
30	Collection and disposal of liquid wastes
31	Collection, treatment and disposal of run-off water
32	Provision of ablution facilities
33	Cleaning of personal mining garments
34	Storing, testing and issuing of lamps and self rescue kits
35	Estate management
<b>Planning, development and maintenance activities</b>	
36	Planning of surface infrastructure and services networks, as well as underground infrastructure, working and emergency facilities and service networks
37	Development of surface infrastructure and services networks
38	Development of underground working and emergency facilities and service networks
39	Maintenance of reef bin system & equipment
40	Maintenance of waste rock dump
41	Maintenance of surface infrastructure, equipment and services networks
42	Maintenance of underground working and emergency facilities, equipment and service networks

**Table 6: Generic facilities, related to generic business processes at a deep level gold mine shaft**

<b>Core mining activities</b>	<b>Supporting activities</b>
Main and up-cast shafts	Electrical sub-station
Winder house	Canteen
Change house	Rescue room
Surface bank area	Range of workshops
Surface cooling related facilities	Range of supply related facilities e.g. stores
Compressor related facilities	Range of storage related facilities e.g. yards & stores
Ventilation fans	Range of solid waste related facilities e.g. wash down, sorting and temporary storage areas
Overhead conveyor facilities	Sewage treatment related facilities
Waste rock dump	

However, clear differences were observed in the infrastructure at the two sites. These differences were related to three aspects, i.e. the time of initial development of the shaft, reflecting the available technologies and general environmental awareness at that time, the age of the site, as well as the stage in the mining life cycle of the shafts (Table 7).

**Table 7:** Effect of time of development, age of site and stage in mining life cycle on deep level gold mine shaft facilities and layout.

<b>Factor</b>	<b>Shaft A</b>	<b>Shaft B</b>
Date of initial development	<ul style="list-style-type: none"> <li>• Early 1970s – facilities related to fairly old technologies, e.g. CFC cooling plant.</li> <li>• Limited, inadequate arrangements to address environmental concerns, e.g. surface water and waste management;</li> </ul>	<ul style="list-style-type: none"> <li>• Early 1990s – facilities related to new technologies, e.g. ammonia cooling plant.</li> <li>• Fairly good arrangements to address environmental concerns, e.g. surface water and waste management;</li> </ul>
Age of site	<ul style="list-style-type: none"> <li>• Infrastructure less well-planned and organised;</li> <li>• Signs of wide-scale upgrading and redevelopment;</li> <li>• Fairly large number of old, abandoned facilities;</li> </ul>	<ul style="list-style-type: none"> <li>• Well-planned and organised Infrastructure;</li> <li>• Upgrading and redevelopment on a limited scale;</li> <li>• Limited number of old, abandoned facilities;</li> </ul>
Stage in mining life cycle	<ul style="list-style-type: none"> <li>• Advanced stage;</li> <li>• Focus on gold ore extraction;</li> <li>• Relative large area allocated to supply stores, storage and maintenance related facilities such as storage areas and workshops, while backfill plant has replaced batch plant.</li> </ul>	<ul style="list-style-type: none"> <li>• Early stage;</li> <li>• Focus on development of mine infrastructure;</li> <li>• Relative large area allocated to development related facilities such as batch plants and relative small area allocated to supply stores, storage and maintenance related facilities such as storage areas and workshops.</li> </ul>

#### **4.3.3. Identifying generic personnel frameworks at a deep level gold mine shaft**

Based on the information about the personnel at Shafts A and B, it was possible to identify a number of generic functions, required to perform the generic business processes and activities at deep level gold mine shafts. These include mineral resources, human resources, working environment (rock mechanics, safety & health, environmental) and a financial management function. The personnel staffing all of these functions should be included in a generic personnel framework for a deep level gold mine shaft.

There were, however, also some distinct differences between the functions and personnel components of the two shafts. At Shaft A separate management units and departments were responsible for the mining function and the infrastructure development and maintenance functions, while these functions were combined into one department at Shaft B.

These differences are possibly again related to the different stages in the mine life cycle in which these shafts are at present, having different requirements for these functions, allowing them to be combined in a younger mine with less developed underground areas, but requiring them to be split in older mines with vast developed underground areas. However, it must also be kept in mind that the personnel structure of the shafts may to some extent also reflect the preferences of the individual mine managers.

### **5. Conclusion**

The results of this study indicate that a generic scope can be developed to describe the business processes, physical boundaries and personnel component of a deep level gold mine shaft, as many common aspects were found between the two shafts studied.

Five generic business processes were identified for deep level gold mine shafts, i.e. planning, development, mining (core & operational support), maintenance and administration. Forty-two generic activities were identified, of which eighteen were related to core mining activities, five to operational support activities, twelve to administrative support activities and the remaining seven to planning, development and maintenance activities. A number of facilities, required to perform the generic business processes and activities, were also identified. In terms of personnel, a number of generic functions were identified which are required to perform the generic business processes and activities at deep level gold mine shafts.

The generic scope model can be useful to determine the scope of any deep level gold mine shaft prior to the development of an environmental management system.

However, this study also illustrated that there are certain non-generic issues at deep level gold mine shafts and sites that must be considered when determining the scope of any such shaft. These primarily relate to the facilities and personnel structure, which seem to be determined by

site specific considerations, such as the local conditions at the site, time of initial development of the shaft, the age of the site, the stage in the mining life cycle of the shaft, as well as the preferences of individual mine managers.

## **References**

- AUSTRALIA. Environment Protection Agency. 1995. Environmental management systems. Best practice environmental management in mining. Commonwealth of Australia. 40 p.
- CHAMBER OF MINES OF SOUTH AFRICA. 1997. Chapter 2: Environment and natural resources management - Annual report for 1996/97. Johannesburg: Chamber of Mines of South Africa. 82 p.
- CHAMBER OF MINES OF SOUTH AFRICA. 2002. The contribution of the mining and minerals industry to sustainable development in South Africa. Johannesburg: Chamber of Mines of South Africa. 12 p.
- EPA. See AUSTRALIA. Environment Protection Agency.
- GILBERT, M.J. 1993. Achieving Environmental Management Standards: A step-by-step guide to meeting BS 7750. London: Pitman Publishing. 234 p.
- GLOBAL ENVIRONMENTAL MANAGEMENT INITIATIVE. 1996. ISO 14001 Environmental Management System Self-Assessment Checklist. Washington: GEMI. 54 p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996a. Environmental management systems - Specification with guidance for use. South African Standard. SABS ISO 14001:1996. South African Bureau of Standards. 14p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996b. Environmental management systems - General guidelines on principles, systems and supporting techniques: South African Standard. SABS ISO 14004:1996. South African Bureau of Standards. 31 p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 2000. Quality management systems – Fundamentals and vocabulary. South African Standard. SABS ISO 9000:2000 ISO edition 2. South African Bureau of Standards. 29p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 2001. Environmental management – Environmental assessment of sites and organisations (EASO). South African Standard. SABS ISO 14015. South African Bureau of Standards. 19p.

- KUHRE, W.L. 1995. ISO 14001 Certification. Environmental management systems: A practical guide for preparing effective environmental management systems. New York: Prentice Hall Inc. 378 p.
- MBENDI. 1997. South Africa - Mining industry profile. 27 Nov. 1997. [Available on Internet:] <http://www.mbendi.co.za/indy/ming/mingsa.html> [Date of use: 16 Mar. 1999]
- MMSD Southern Africa see Mining, Minerals & Sustainable Development Southern Africa.
- MINING, MINERALS & SUSTAINABLE DEVELOPMENT SOUTHERN AFRICA. 2002. Volume 1. The report of the regional MMSD process. Johannesburg: School of Mining Engineering, University of the Witwatersrand. 77p.
- NEL, J.G. 2002. Module 7. Pre-implementation considerations. (Paper delivered as part of a short course in ISO14001 Environmental Management Systems at the PU for CHE) Potchefstroom. 22p.
- SOUTH AFRICA. Department of Minerals and Energy. 1998. White paper on a Minerals and mining Policy for South Africa. Pretoria. 67p.
- STAPLETON, P.J., COONEY, A.M. & HIX, W.M. 1996. Environmental management systems: An implementation guide for small and medium-sized organisations. NSF International. Michigan: Ann Arbor. 160 p.
- VERSTER, J.J. & VAN LUITINGH, P. 1997. SA's mineral role within the SADC. Mining magazine, 177(1):48, Jul.
- WELLS, J.D., VAN MEURS, L.H. & RABIE, M.A. 1992. Terrestrial minerals. (In Fuggle, R.F & Rabie, M.A., eds. Environmental management in South Africa. Cape Town: Juta & Co, Ltd. p. 337-379.
- WEST G.A. & MANTA J.G. 1996. ISO 14001: An Executive Report. Rockville: Government Institutes Inc. 106 p.

## **Chapter 3**

### **Implementing Environmental Management Systems to improve sustainable development in gold mining:**

#### **2. Environmental impacts and aspects of deep level gold mine shafts in South Africa.**

TC Meyer <sup>(1)</sup>

(1) Centre for Environmental Management, Potchefstroom University

#### **Abstract**

South Africa is one of the world's foremost and most diverse mining and mineral processing nations and mining and its associated industries continue to form the cornerstone of the economies of most southern African countries. Mineral resources hold the promise of long-term social and economic benefits for the region, which are recognised as a key component of the New Partnership for Africa's Development (NEPAD).

However, few, if any, economic activities pose as great a threat to the environment as mining. The mining industry has, by its very nature, the potential to endanger human health and safety, as well as the physical environment. As an activity that is dependent on the winning of minute amounts of useful products from vast tonnage of ore, mining will always contend with major environmental challenges and remain under constant public pressure to demonstrate commitment to responsible environmental management.

The key to effective environmental management is the use of a systematic approach to plan, control and improve environmental efforts. An Environmental Management System (EMS) employs such an approach and allows organisations to address environmental concerns in an orderly and consistent manner. It allows organisations to anticipate and meet their environmental objectives and to ensure ongoing compliance with national and/or international requirements.

Although a few gold mines in South Africa have implemented an EMS, the question of which significant environmental aspects need to be managed in such a system at a deep level gold mine shaft, remains largely unanswered. This paper is one of two that will endeavour to provide answers to this question and to develop a generic scope for the business processes, physical boundaries and personnel component of a deep level gold mine shaft. Such a model should facilitate the development and implementation of an EMS at such shafts in the gold mining industry.

This study has identified significant environmental impacts and aspects related to the activities, products and services at deep level gold mine shafts in South Africa. It has also identified some generic business activities at such shafts that are potentially destructive and carry a high risk of causing significant negative environmental impacts at such shafts. In identifying these, this study has contributed to a generic model for the initial environmental review process that precedes the development of an environmental management system at deep level gold mine shafts.

## **Uittreksel**

Suid-Afrika is een van die wêreld se voorste en mees diverse mynbou- en minerale prosesseringsnasies en die mynboubedryf is baie belangrik vir die land se ekonomie. Ten spyte van onlangse negatiewe ekonomiese neigings en druk op kommoditeitspryse, bly mynbou en die geassosieerde nywerhede die hoeksteen van die meeste suider Afrikaanse lande se ekonomieë. Minerale hulpbronne hou die belofte in van langtermyn sosiale en ekonomiese voordele vir die streek. Sulke potensiële voordele word erken as 'n sleutelkomponent van die Nuwe Vennootskap vir die Ontwikkeling van Afrika (NEPAD).

Baie min, indien enige, ekonomiese aktiwiteite hou egter so 'n groot bedreiging in vir die omgewing as mynbou. Die kern van mynbou-aktiwiteite, naamlik die onttrekking van baie klein hoeveelhede bruikbare produkte vanuit massiewe hoeveelhede erts, is potensieel skadelik vir mense se gesondheid en veiligheid, asook die omgewing. Daarom sal mynbou altyd gekonfronteer word deur groot omgewingsuitdagings en onder konstante druk verkeer om sy verbintenis tot verantwoordelike omgewingsbestuur te demonstreer.

Die toepassing van 'n sistematiese benadering tot beplanning, beheer en verbeterde bestuur is die sleutel tot doeltreffende omgewingsbestuur. 'n Omgewingsbestuurstelsel (OBS) gebruik so 'n benadering en stel organisasies in staat om hulle omgewingskwessies op 'n ordelike en konsekwente wyse aan te spreek. Dit stel organisasies ook in staat om hulle omgewingsdoelwitte te antisipeer en te bereik, asook om voortdurende nakoming van nasionale en internasionale vereistes te verseker.

Alhoewel 'n paar goudmyne in Suid-Afrika alreeds 'n OBS geïmplementeer het, bly die vraag oor watter betekenisvolle omgewingsaspekte in so 'n stelsel by 'n diep ondergrondse goudmynskag aangespreek moet word, grootliks onbeantwoord. Hierdie artikel is die eerste van twee waarin gepoog sal word om antwoorde op hierdie vraag te verskaf en 'n generiese model vir die basislyn-opnameproses (initial review process) vir 'n diep ondergrondse goudmynskag te ontwikkel. So 'n model kan die ontwikkeling en implementering van 'n OBS by sulke skagte in die goudmynbedryf 'n hupstoot gee.

Hierdie studie het betekenisvolle omgewingsimpakte en -aspekte van die aktiwiteite, produkte en dienste van diep ondergrondse goudmynskagte in Suid-Afrika geïdentifiseer. Dit het ook sekere generiese besigheidsaktiwiteite by sulke skagte geïdentifiseer wat potensieel skadelik is en 'n hoë risiko inhou om betekenisvolle negatiewe omgewingsimpakte te veroorsaak. In hierdie opsig het hierdie studie bygedra tot 'n generiese model vir die basislyn-opnameproses wat die ontwikkeling van 'n OBS by diep ondergrondse goudmynskagte in Suid-Afrika voorafgaan.

## **1. Introduction**

The highly mineralised nature of many parts of South Africa has led to the creation of a mining industry, which is very important to the country's economy. Consequently, South Africa is one of the world's foremost and most diverse mining and mineral processing nations

(Wells *et al.* 1992:362; Verster & Van Luitingh, 1997; Mbendi, 1997; Chamber of Mines of South Africa, 2002:2). Despite recent adverse economic features and depressed commodity prices for many metals and mineral products, mineral resources still hold the promise of long-term social and economic benefits for most southern African countries, while mining and its associated industries continue to form the cornerstone of the economies of the region (MMSD Southern Africa, 2002:12). . Such potential benefits are recognised as a key component of the New Partnership for Africa's Development (NEPAD) (MMSD Southern Africa, 2002:5).

However, few, if any, economic activities pose as great a threat to the environment as mining. As an activity that is dependent on the winning of minute amounts of useful products from vast tonnage of ore, mining activities impact on the environment to varying degrees and will always contend with major environmental challenges. Mineral deposits are potential sources of wealth, and the significance of deposits only become evident when the minerals are mined, resulting in the disturbance of the natural environment, while consuming a range of natural and other resources. Consequently, the mining industry has, by its very nature, the potential to endanger human health and safety, as well as the physical environment. Therefore, the mining sector is under constant public pressure to demonstrate commitment to responsible environmental management (Chamber of Mines of South Africa 1997:29; Chamber of Mines of South Africa, 2002:2).

The use of a systematic approach to plan, control and improve environmental efforts provides the key to effective environmental management. Potentially significant environmental improvements can be achieved by improving an organisation's management processes (Stapleton *et al.* 1996:4). Although a few gold mines in South Africa have implemented environmental management systems, there is still some uncertainty about which significant environmental aspects need to be managed by such a system at a deep level gold mine shaft.

This paper will endeavour to provide some answers to this question, by exploring the possibility of identifying generic environmental impacts and aspects for deep level gold mine shafts in South Africa, as essential part of a generic model for the ISO 14001 initial review process at such shafts. Such a model could facilitate the development and implementation of environmental management systems at deep level shafts in the gold mining industry. The following key questions will be addressed:

- Which are the significant environmental impacts and aspects of deep level gold mine shafts?
- Which are the business activities that could result in significant environmental aspects at deep level gold mine shafts?

- Which generic aspects should be considered in a generic model for the initial environmental review process at a gold mine shaft?

Mine residue deposits originating from metal extraction processes constitute one of the main environmental impacts of mining. Although these deposits originate from the rock being extracted from the shaft, it is an indirect impact of the shaft activities and therefore they were excluded from this study.

## **2. Study area**

The study was undertaken at two gold mine shaft business units of the world's largest gold producer and holder of the most substantial gold reserves. Both are deep level operations in the vicinity of Orkney in South Africa, extracting gold from placer deposits, mining at an average depth of 2100 metres below surface. In order to account for the possible impact that the time of initial development of the shaft, as well as the age and stage in the mining life cycle could have on the scope of a deep level gold mine shaft, the two shafts differ distinctly in respect of these parameters.

Shaft A commenced production in 1972. It is among the deepest shafts in South Africa, operating over eight main levels with an average depth of 2400m. This low-cost high-value shaft is currently operating at full capacity. It is expected that this will continue over the expected 15 remaining years of the mine's life, but yields are expected to decline and tonnage to drop in steps. Therefore, the focus at this shaft is on maintaining its low-cost profile as grades drop.

Shaft B is located adjacent to shaft A and is still being developed to exploit a mineral resource that lies between 2,100 m and 3,700 m below surface. The plan is to establish a modern mine through implementation of the latest technology. Development at the shaft started in 1991, while the main shaft was commissioned in 1998 and by the end of 2000 had been sunk and equipped to a depth of 2.400 m. The development of the infrastructure is under way through the temporarily equipped rock ventilation shaft and will continue for several years to come. Currently, the trackless method of development is employed. This modern shaft is economic to run and is expected to reach full production by 2008.

The empirical part of the study was conducted over the period November 1999 to August 2000 and the information regarding the scope of the shaft business units were valid at the time of the study. Due to changing circumstances and conditions at these shafts, it is possible that the information on the scope of the specific shaft business units might have changed since then. However, the aim of the study was not to evaluate the actual situation

at a specific shaft on any specific moment, but rather to develop a generic scope for deep level gold mine shafts. As such, the outcomes of the study are still considered to be valid.

### 3. Experimental procedure

#### 3.1. The initial review process.

ISO 14001:1996 (sub-clause 4.3.1) requires organisations to establish procedures for identifying significant environmental aspects that should be addressed as a priority by the organisation's environmental management system (EMS). The process of identifying all environmental aspects, impacts, risks and problems is possibly the most taxing and time consuming part of developing an EMS. An organisation with no existing environmental management system should, initially, establish its current position with regard to the environment by means of a review. However, organisations with operating environmental management systems do not have to undertake such a review (International Organization for Standardization, 1996a:7).

The initial review is a fact-finding review of the whole organisation intended to establish a benchmark on an organisation's environmental performance. To ensure that the environmental aspects of the organisation are assessed as a basis for establishing the EMS the initial review process should consider all inputs and outputs associated with the activities, products and processes of an organisation (Gilbert, 1993:62, 118; International Organization for Standardization, 1996a:7). This process can be equated to an environmental impact assessment (EIA) that should reveal the potential environmental impacts of a mine during its lifetime. As the vital first stage element in devising strategies to control these effects and managing the environment on a site, it is the foundation of the EMS. The findings should form the initial objectives, targets and procedures that an organisation must achieve or implement (EPA, 1995:4,16).

The International Organization for Standardization (1996a:7) states that the initial review should cover four key areas. These areas, as expanded on by Kuhre (1995:67); Gilbert (1993:68) and the International Organization for Standardization (1996b:5) are summarised in Table 1.

**Table 1:** Key areas to be covered by the initial review, with types of information to be considered.

<b>Key area #1</b>	<p><b>Identification and evaluation of applicable legislation and regulatory requirements</b></p> <p>Consider existing policies and programmes, the organisation's current performance with regard to relevant internal criteria, external standards, regulations, codes of practice, as well as sets of principles and guidelines.</p>
--------------------	---

Type of information to consider	Current legal obligations and consents Future regulations Communication with regulators	Product legislation Marketplace legislation Waste controls
<b>Key area #2</b>	<b>Identification and evaluation of environmental aspects/ processes/ products/risk areas</b> Consider all activities, products or services of organisations in order to determine those that have or can have significant environmental impacts and liabilities.	
Type of information to consider	Raw material sources Suppliers performance Transport and distribution Water quality and use Energy management and use Types and volumes of waste Waste storage and disposal methods Recycling or reuse status	Duty of care compliance Discharges Heat, light and power Product design Packaging Consumer management BATNEEC analysis BEO analysis
<b>Key area #3</b>	<b>Examination of all existing environmental management practices and procedures</b>	
Type of information to consider	Environmental policy Environmental strategy Environmental responsibilities Materials and equipment supplies Products assessments Procurement policy Procurement practices and procedures Contracting practices and procedures Insurance and indemnities	Investment plans Project assessments Training and skills base Environmental records Environmental audits Environmental reporting Environmental reviews Communications Public relations
<b>Key area #4</b>	<b>Evaluation of feedback from previous accidents or failures</b>	
Type of information to consider	Non-compliance records Incident and accident records Emergency response training Emergency planning	Contingency plans Progress or action plans Communication strategy

In terms of environmental impacts, the initial review should cover the inputs and outputs generated by material and energy flows at the site. The main inputs that should be considered are raw, operating and packaging materials, energy, water, air, and soil, while the main outputs that should be considered are products and services, waste materials, wastewater, exhaust air, noise and odours.

Other areas that might also be considered during the initial review include community perceptions of the organisation's environmental aspects and activities; customer perceptions of the environmental characteristics of the organisation's products and services, existing processes, documentation, work practices and opportunities for competitive advantage. Functions or activities of other existing organisational systems, such as quality systems already in place, that can enable or impede environmental performance; opportunities for technology sharing, joint ventures, and strategic alliances to obtain a competitive advantage,

might also be considered (Gilbert, 1993:62-63; International Organization for Standardization, 1996b:5).

The initial review process is intended to identify significant environmental aspects associated with activities, products, or services, and is not intended to require a detailed life cycle assessment. Organizations do not have to evaluate each product, component or raw material input. They may select categories of activities, products or services to identify those aspects most likely to have a significant impact (International Organization for Standardization, 1996a:7).

A process-based approach where generic business processes was first identified, after which specific activities were identified for the identified generic business processes, was followed to develop a generic scope for deep level gold mine shafts in South Africa (Meyer & Van der Walt, in press). Activities directly related to the ore extraction process (core mining activities) and supporting activities such as planning, development, maintenance, administrative and operational support activities were used as the basis for identifying 42 generic activities (Table 2), which were used as the framework for identifying and evaluating the impacts and aspects of the shafts.

### **3.1.1. Identifying and assessing the environmental impacts and aspects of deep level gold mine shafts**

The relationship between environmental aspects, environmental impacts and the EMS is an important consideration when implementing an ISO14001 EMS. The elements of the EMS are shaped around the organisation's environmental aspects and (potential or actual) environmental impacts, as ISO 14001:1996 demands aspect management. Consequently, the development and implementation of the ISO14001:1996 EMS hinges on a clear understanding of the concepts of environmental aspect and environmental impact.

**Table 2: Generic activities related to the business processes at a gold mine shaft**

<b>Core mining activities</b>	
1	Horizontal movement of people to and from shaft
2	Loading equipment and supplies onto trams and unloading
3	Horizontal transport of equipment, material and wastes to and from shaft on trams
4	Loading trams into cages
5	Vertical transport of people, equipment, material and wastes
6	Horizontal transport of people, equipment and material, wastes underground
7	Drilling holes in rock face
8	Preparation of explosives
9	Transporting explosives to underground workings
10	Loading of explosives into shot holes
11	Blasting rock
12	Scraping and clearing of blasted rock
13	Installation of roof support systems
14	Horizontal transport of broken rock (ore and waste rock)
15	Vertical transport of broken rock to surface
16	Horizontal transport of broken rock on surface
17	Storing of ore in reef bins
18	Dumping of waste rock on waste rock dump
<b>Operational support activities</b>	
19	Provision of compressed air
20	Provision of ventilation
21	Provision of potable water
22	Collection, settling, treatment, cooling and recycling of mine service water
23	Provision of electricity and lighting
<b>Administrative support activities</b>	
24	Provision of personnel management functions
25	Provision of food
26	Initial medical treatment of injured personnel
27	Administration of mining activities, materials, equipment and systems
28	Administration of waste disposal system
29	Washing, sorting, recycling and disposal of solid wastes
30	Collection and disposal of liquid wastes
31	Collection, treatment and disposal of run-off water
32	Provision of ablution facilities
33	Cleaning of personal mining garments
34	Storing, testing and issuing of lamps and self rescue kits
35	Estate management
<b>Planning, development and maintenance activities</b>	
36	Planning of surface infrastructure and services networks, as well as underground infrastructure, working and emergency facilities and service networks
37	Development of surface infrastructure and services networks
38	Development of underground working and emergency facilities and service networks
39	Maintenance of reef bin system & equipment
40	Maintenance of waste rock dump
41	Maintenance of surface infrastructure, equipment and services networks
42	Maintenance of underground working and emergency facilities, equipment and service networks

ISO 14000:1996 defines environmental impact as “any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation’s activities, products, or services”, while an environmental aspect is defined as any “element of an organisation’s activities, products and services which can interact with the environment” and a significant environmental aspect is one that “has or can have a significant environmental impact.” (International Organization for Standardization, 1996a:1,2).

The identification of environmental aspects and the evaluation of associated environmental impacts is a process that can be dealt with in four steps (International Organization for Standardization, 1996b:8):

- **Step 1 - Select an activity, product or service**

The selected activity, product or service should be large enough for meaningful examination and small enough to be sufficiently understood.

- **Step 2 - Identify environmental aspects of the activity, product or service**

Identify as many environmental aspects as possible associated with the selected activity, product or service.

- **Step 3 - Identify related environmental impacts**

Identify as many actual and potential, positive and negative, environmental impacts as possible associated with each identified aspect.

- **Step 4 - Evaluate significance of impacts**

Once the environmental aspects of an organisation’s products, activities and services have been identified, it should be determined which aspects could have significant impacts on the environment. The significance of the identified environmental impacts can be different for each organisation.

ISO 14015 provides guidance on how to conduct environmental assessments of sites and organizations (EASO) through a systematic process of objectively identifying and evaluating environmental issues/aspects associated with sites and activities, as a result of past and current activities (International Organization for Standardization, 2001:v).

**Table 3:** Basic steps of the EASO process (International Organization for Standardization, 2001: 2).

Step	Activities
Plan the assessment	Define objectives, determine scope, determine assessment criteria, develop the assessment plan
Gather & validate information and data	Review existing documentation and records, observe activities and physical conditions, and interview relevant personnel
Evaluate information & data	Validate all information and data to identify and evaluate environmental issues
Report on findings of the assessment	

The EASO process formed the basis of the assessment - identification and evaluation of impacts and aspects - followed in this study. The identification and evaluation of environmental impacts and associated aspects were done by selecting an activity, product or service, identifying the environmental impacts thereof, identifying the associated aspects and evaluating the significance of the impacts.

#### **3.1.1.1. Assessment plan**

The objective of the assessment was to identify, gather and evaluate information on the environmental aspects associated with the site and organisation, in order to highlight those that should be addressed as a priority by an environmental management system. The scope of the assessment was limited to the scope of the gold mine shafts. The criteria for the assessment were derived from ISO14001, i.e. environmental aspects and impacts associated with the site and activities, the company's environmental policy, as well as current environmental legislation, regulations and permits.

The criteria for determining significance of environmental aspects were derived from a water management environmental review done for Shaft B. The review used severity, spatial scale, duration and likelihood as criteria for determining significance, which are similar to the intensity, extent, duration and probability criteria published by the Department of Environmental Affairs and Tourism in the guideline document to the EIA process (South Africa, 1998:27-28). Due to the fact that both gold mine shafts were familiar with the methodology developed in-house, these criteria were also used in this study to determine the significance (risk) of the aspects identified.

### **3.1.1.2. Collecting and validating information and data on environmental impacts and aspects**

There are many different ways of collecting and validating the required information. Various methods are often complementary and should be used together as part of an overall approach for carrying out the initial review. The assessment of environmental aspects and impacts is based on validated information on these gathered during the initial review process. Information was collected through reviewing existing documents and records (both prior to and during the site visit), observing activities and physical conditions on site and interviewing mine personnel and contractors. Care was taken to ensure that the information and data collected were sufficient, relevant and accurate for the purpose of the assessment.

- **Survey of available documents and records**

Various documents were obtained from the organisation. The documents that proved the most valuable included the approved Environmental Management Programme Report (especially chapter 6) and a legal register for the parent organisation, as well as preliminary initial environmental reviews for both organisations and various external reports regarding the general impact of gold mining activities on ground and surface water in the area. Other supporting documents included a draft water use application for the parent organisation, as well as site maps, current permits and internal letters and reports. Records, such as inventories of supplies, including pollutant and hazardous materials, waste inventories, material safety data sheets, process documents and accident records were also reviewed. Data and information that proved helpful related to regular water monitoring and water balances, as well to waste recycling.

All the documents were reviewed to obtain a sufficient understanding of the environmental impacts and aspects of the organisation. Relevant information was extracted and used to compile checklists and questionnaires of all the areas that needed to be reviewed during the site visit and interviews. These checklists formed the basis for the interviews and site visit.

- **Interviews**

Interviews with individual employees prior to, during and after the site visits, formed an essential part of the initial review. These interviews were conducted with the approval of the client organisations. Interviews were also conducted with contractors and personnel from neighbouring organisations, such as the metallurgical plant.

Employees at all levels proved to be a most valuable source of information. Although the employees who work in the production areas were seldom able to provide exact figures on impacts, they generally knew what the main problem areas were. Supervisors and

managers, on the other hand, were able to provide more exact data related to a number of issues.

Interviews were used to gather more detailed information on the environmental impacts and aspects of shafts. The checklists and questionnaires developed during the document review process were used as a basis for the interviews to ensure that the activities of the shafts were covered in detail. Apart from being relatively quick, cheap to implement and easy to use, the checklists and questionnaires also had the advantage of being flexible allowing for updates during the initial review process, as experience and information were improved.

Information gathered was used to corroborate or augment information from the review of existing documents, as well as from observations made during the site inspections.

- **Site inspections**

During the site visits, information regarding the physical condition of the sites, due to past and current operations were observed and recorded. These inspections were also used to gather more detailed information on the past, present and potential environmental impacts of the organisations, as well as current arrangements to deal with environmental issues. Observations were primarily limited to those able to be detected using natural senses, but sampling and testing were also carried out in specific instances to verify observations. All observations were supported with written records. The information gathered was used to corroborate or augment information from the document reviews, as well as from claims made during the interviews.

### **3.1.1.3. Evaluating the information and data on environmental impacts and aspects**

The identified criteria were used as discussed below to evaluate the environmental impacts of the shafts.

**Severity (*intensity*)** was rated as

- low (1) – where the impact affects the environment in such a way that natural and social functions and processes are not affected;
- medium (6) - where the affected environment is altered, but natural and social functions and processes continue albeit in a modified way; or
- high (10) - where natural and social functions or processes are altered to the extent that it will temporarily or permanently cease.

The rating was based on a number of considerations, i.e. the degree to which:

- the activity, product or service violates the spirit or letter of any law, statute, regulation or authorisation;
- the activity, product or service affects public health and safety (level of toxicity etc.);

- the activity, product or service affects the availability or functioning of life support systems or other environmental goods, services and conditions which are considered to be of special or unique character, of limited supply or essentially irreplaceable;
- the activity, product or service is related to other impacts which individually are insignificant, but could cumulatively result in significant impacts;
- an activity, product or service may establish a precedent for future actions with significant environmental impacts or represents a decision in principle about an issue with significant implications;
- the potential impacts of the activity, product or service is highly uncertain or involves unique or unknown risks; and
- the degree of irreversibility.

**Spatial scale (extent)** was rated as

- local (1) - where the impact would extend only as far as the activity, product or service;
- site (2) - where the impact would be limited to the site and its immediate surroundings; or
- regional, national or international (3) – where the impact would extend to the region or have an impact on a national scale or across international borders.

**Duration** was rated to indicate whether the lifetime of the impact would be

- short term (1) – where the impact would exist for hours or weeks;
- medium term (2) – where the impact would exist for the life of the mine (5-15 years); or
- long term – where the impact would exist beyond the life of the mine (>15 years).

The **consequences** of the environmental aspects were calculated by summing the values for the first three criteria, i.e. severity, spatial scale and duration. This consequence value was multiplied by the value for the fourth criterion, **likelihood**, to arrive at the **significance (risk)** of the aspects.

The **likelihood** of the occurrence of the impact was rated as

- unlikely (0.5) - where the frequency of the impact or the probability of the impact harming the environment or public health is extremely low;
- likely (0.8) - where there is a distinct possibility that the impact will occur and harm the environment or public health; or
- definite (1.0) - where there impact will occur regardless of any prevention measures and the environment and public health will be harmed.

The significance (risk) ratings were to reflect whether the significance of the impact was

- low – value <6
- medium – value between 6 and 9.9
- high – value >10.

Where an environmental impact was regulated by law, any environmental aspect related to a legal non-compliance was also rated as high.

#### **3.1.1.4. Documenting the findings on the environmental impacts and aspects**

All results of the interviews and site visits, as well as quantitative information from data-sheets, inventories, etc. were recorded and used as the basis for the register of environmental impacts. Comparing the validated data and information gathered on environmental aspects against the predetermined criteria, in a manner consistent with the scope and objectives of the assessment, resulted in a list of rated environmental issues that need to be addressed by the environmental management system.

Matrices are designed to stimulate thought about possible consequences of specific actions, thereby ensuring comprehensiveness as well as precision in analysis and are frequently used in environmental evaluation. Through a methodical analysis of all activities and processes, and the components of the environment they are likely to affect, a matrix provides the comprehensive picture that is needed to identify issues and determine their significance. The Leopoldt matrix was developed in the USA as a tool in impact analysis. The simple expedient of dividing the checklist into two data sets (one related to environmental elements and the other to human activities), and arranging the two sets at right angles so as to form a cross tabulation or matrix, greatly expanded the scope and usefulness of checklists. This cross tabulation provides an easy way of focussing thinking onto particular issues that may cause concern. The method is comprehensive and precise, highly adaptable to various projects and environments and incorporates fundamental information on first-order cause-effect relationships. The format also provides a useful means for displaying and summarising a lot of information that will be required by those assessing an activity. The method furthermore also identify problem areas in a precise way, allowing efforts to be applied constructively in overcoming specific rather than nebulous problems (Fuggle 1992:767,768).

A modified Leopoldt matrix was used to document the findings of the impact and aspect assessment in this study in as much detail as possible. The matrix was compiled by entering the 42 generic mining related activities of the deep level gold mine shafts on the Y-axis. The specific broad characteristics (e.g. water availability, water quality, air quality, soil quality, soil availability, land availability etc.) of the affected environmental media (water, soil, energy, air, waste, biodiversity, land and topography) were used as framework to list all the potential environmental impacts on the X-axis. For example, consumption of potable water and mines service water during operations was identified as an impact on the medium water and specifically water availability. In a similar fashion air pollution due to the release of CFC or

NH<sub>3</sub> gas from the refrigeration systems was identified as an impact on the medium of air and specifically air quality.

The X-axis was further expanded by identifying and adding the potential aspects of the identified environmental impacts, or elements of the activities, products or services that can interact with the environment. These elements included aspects such as inadequate facilities to allow for the separation of clean and dirty (polluted run-off) water on the surface area of Shaft A, inadequate working procedures to deal with incidents such as spillage of oil or other chemicals at both shafts, no or inadequate measures to reduce (minimise) electricity consumption at both shafts, as well as an activity such as the watering of the waste rock dump, all of the last three aspects observed at both shafts. The term arrangements is used in the tables to collectively refer to facilities, measures and working procedures.

The matrix was completed by interpreting and evaluating each individual co-ordinate, i.e. direct cause-effect relationships. The evaluation was done through critically evaluating the significance of each individual activity-aspect relationship. The ratings were done according to the identified criteria, discussed above. The completed matrix provides a detailed record of judgements on the significance of the environmental aspects of a deep level gold mine shaft. Therefore, the matrix was reviewed to reveal areas of particular concern, of high risk or areas where further investigations are required. Apart from the consideration of individual cells, the review also considered the total effects of specific actions, and total effects on particular environmental characteristics. This was done by considering clusters, or individual rows and columns of the matrix as entities. It helped to identify sensitive or vulnerable environments or environmental components, as well as destructive or critical activities. It also helped to identify environmental elements subject to numerous small impacts, which could cumulatively be of significance, and similarly identify actions of no particular significance but with a widespread low-key effect.

## **4. Results**

### **4.1. Significant environmental impacts and aspects of generic business activities at deep level gold mine shafts**

The identification of environmental impacts and aspects, as well as the evaluation of the significance of the environmental impacts was done in accordance with the information gathered during the information and data collection exercise.

#### 4.1.1. Environmental impacts of deep level gold mine shafts

The activities, products and services at Shafts A and B had a wide range of impacts on the physical environment. A total number of 26 potential environmental impacts were identified at these shafts (Tables 4 and 5). Water seems to be the environmental element that is subject to the highest number of impacts (nine), while the activities, products and services at the shafts also impacted on air (four impacts), soil and land (three impacts each), waste and topography (two impacts each and energy (one impact). Water pollution (negative impact on water quality) seems to be the major environmental problem faced by deep level gold mine shaft as reflected by the identification of six environmental impacts related to this problem. (Table 6).

**Table 6:** Relationship between environmental parameters and environmental impacts and aspects

Environmental medium	Environmental parameter	Number	
		Environmental impacts	Environmental aspects
Water	Water availability	3	3
	Water quality	6	9
Soil	Soil availability	1	1
	Soil quality	2	4
Energy	Coal availability	1	1
Air	Air quality	4	4
Waste	Waste generation	1	1
	Waste management	1	3
Biodiversity	Biodiversity loss	3	4
Land	Land availability	1	1
	Land use capability	2	2
Topography	Topography changes	2	2

**Table 4a: Environmental impacts and aspects of mining activities at Shaft A**

Environmental parameter	Water			Soil			Energy													
	Water availability	Water quality	Soil quality	Water availability	Soil quality	Energy availability	Water availability	Water quality	Soil quality											
Environmental impact	Consumption of potable and mine service water during operations	Lack of sufficient arrangements to minimise water consumption during operations	Lack of sufficient arrangements to separate clean and polluted surface run-off water	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted surface run-off water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted mine service water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Surface water pollution due to release of pollutants from exposed surface	Surface water pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Soil pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to minimise electricity consumption during operations	Deposition of non-renewable coal resources due to consumption	Lack of sufficient arrangements to minimise electricity consumption in order to minimise coal consumption during electricity generation	Lack of sufficient arrangements to remediate / rehabilitate polluted soils	Lack of sufficient arrangements to minimise electricity consumption in order to minimise coal consumption during electricity generation	
	Consumption of water during electricity generation	Lack of sufficient arrangements to minimise timber consumption during operations in order to reduce water consumption by timber plantations	Lack of sufficient arrangements to separate clean and polluted surface run-off water	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted surface run-off water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted mine service water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Surface water pollution due to spillage of pollutants (oil, paint, other chemicals etc.) during operations	Surface water pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Soil pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to minimise electricity consumption during operations	Deposition of non-renewable coal resources due to consumption	Lack of sufficient arrangements to remediate / rehabilitate polluted soils	Lack of sufficient arrangements to minimise electricity consumption in order to minimise coal consumption during electricity generation	
	Environment aspect	Lack of sufficient arrangements to minimise electricity consumption during operations	Lack of sufficient arrangements to separate clean and polluted surface run-off water	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted surface run-off water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted mine service water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Surface water pollution due to spillage of pollutants (oil, paint, other chemicals etc.) during operations	Surface water pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Soil pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to minimise electricity consumption during operations	Deposition of non-renewable coal resources due to consumption	Lack of sufficient arrangements to remediate / rehabilitate polluted soils	Lack of sufficient arrangements to minimise electricity consumption in order to minimise coal consumption during electricity generation	
	Core mining activities	Lack of sufficient arrangements to minimise electricity consumption during operations	Lack of sufficient arrangements to separate clean and polluted surface run-off water	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted surface run-off water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to collect, treat, recycle and dispose of polluted mine service water	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Surface water pollution due to spillage of pollutants (oil, paint, other chemicals etc.) during operations	Surface water pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Lack of sufficient arrangements to prevent / contain / clean up pollutant spillages during operations	Soil pollution due to release of pollutants from exposed waste rock on surface	Soil pollution due to release of pollutants from exposed waste rock on surface	Lack of sufficient arrangements to minimise electricity consumption during operations	Deposition of non-renewable coal resources due to consumption	Lack of sufficient arrangements to remediate / rehabilitate polluted soils	Lack of sufficient arrangements to minimise electricity consumption in order to minimise coal consumption during electricity generation	
	1 Horizontal movement of people to and from shaft	M																		
	2 Loading equipment and supplies onto trams and unloading																			
	3 Horizontal transport of equipment and material, wastes to and from shaft on trams																			
	4 Loading trams into cages																			
	5 Vertical transport of people, equipment, material and wastes																			
	6 Horizontal transport of people, equipment and material, wastes underground																			
	7 Drilling holes in rockface																			
	8 Preparation of explosives																			
	9 Transporting explosives to underground workings																			
	10 Loading of explosives into shot holes																			
	11 Blasting rock																			
	12 Scraping and clearing of blasted rock																			
	13 Installation of roof support systems																			
	14 Horizontal transport of broken rock (ore and waste rock)																			
15 Vertical transport of broken rock to surface																				
16 Horizontal transport of broken rock on surface																				
17 Storing of ore in reef bins																				
18 Dumping of waste rock on waste rock dump																				













**Table 5b: Environmental impacts and aspects of mining activities at Shaft B (continued)**

Environmental parameter	Air		Waste		Biodiversity			Land		Topography	
	Air quality	Waste generation	Waste management	Biodiversity richness	Land availability	Land use capability	Topography changes				
Environmental impact	Air pollution due to NH3 gas releases from refrigeration system	Lack of/insufficient arrangements to prevent / minimise NH3 gas emissions from refrigeration system	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation
	Air pollution due to harmful gaseous emissions during operations	Lack of/insufficient arrangements to prevent / minimise harmful gaseous emissions from refrigeration system	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation
Environmental aspect	Air pollution due to greenhouse and other harmful gas emissions during electricity generation	Lack of/insufficient arrangements to prevent / minimise electricity consumption in order to minimise emissions during electricity generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation
	Air pollution due to generation of hazardous, radioactive, sewage, construction and other wastes during operations	Lack of/insufficient arrangements to reduce, recycle, re-use and reclaim wastes	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation	Lack of/insufficient arrangements to prevent / minimise dust generation
Core mining activities	1 Horizontal movement of people to and from shaft	M	M	M	M	M	M	M	M	M	M
	2 Loading equipment and supplies onto trams and unloading	M	M	M	M	M	M	M	M	M	M
Core mining activities	3 Horizontal transport of equipment and material, wastes to and from shaft on trams	M	M	M	M	M	M	M	M	M	M
	4 Loading trams into cages	M	M	M	M	M	M	M	M	M	M
Core mining activities	5 Vertical transport of people, equipment, material and wastes	H	M	M	M	M	M	M	M	M	M
	6 Horizontal transport of people, equipment and material, wastes underground	M	M	M	M	M	M	M	M	M	M
Core mining activities	7 Drilling holes in rockface	M	M	M	M	M	M	M	M	M	M
	8 Preparation of explosives	M	M	M	M	M	M	M	M	M	M
Core mining activities	9 Transporting explosives to underground workings	M	M	M	M	M	M	M	M	M	M
	10 Loading of explosives into shot holes	M	M	M	M	M	M	M	M	M	M
Core mining activities	11 Blasting rock	M	M	M	M	M	M	M	M	M	M
	12 Scraping and clearing of blasted rock	M	M	M	M	M	M	M	M	M	M
Core mining activities	13 Installation of roof support systems	M	M	M	M	M	M	M	M	M	M
	14 Horizontal transport of broken rock (ore and waste rock)	M	M	M	M	M	M	M	M	M	M
Core mining activities	15 Vertical transport of broken rock to surface	H	M	M	M	M	M	M	M	M	M
	16 Horizontal transport of broken rock on surface	M	M	M	M	M	M	M	M	M	M
Core mining activities	17 Storing of ore in reef bins	M	M	M	M	M	M	M	M	M	M
	18 Dumping of waste rock on waste rock dump	M	M	M	M	M	M	M	M	M	M









#### **4.1.2. Environmental aspects of deep level gold mine shafts**

A total number of 24 unique potential aspects relating to environmental impacts were identified at Shafts A and B (Tables 4 and 5). The following nine of these aspects caused at least two impacts each:

- a lack of or insufficient arrangements to minimise electricity consumption during operations;
- a lack of or insufficient arrangements to minimise timber consumption during operations;
- a lack of or insufficient arrangements to prevent or contain or clean up pollutant spillage during operations;
- a lack of or insufficient arrangements to collect, treat and recycle or dispose of polluted surface run-off water;
- the watering of the waste rock dump;
- a lack of or insufficient arrangements to prevent or minimise the release of pollutants from waste rock;
- a lack of or insufficient arrangements to clean up waste rock spillage;
- a lack of or insufficient arrangements to remove waste rock and mine infrastructure at mine closure;
- a lack of or insufficient arrangements to remediate surface subsidence caused by mining activities.

For example, a lack of or insufficient arrangements to minimise electricity consumption during operations causes negative impacts on water availability, coal availability and air quality through the consumption of water and coal and the release of greenhouse and other harmful gas emissions during electricity generation. Similarly, a lack of or insufficient arrangements to prevent or contain or clean up pollutant spillage during operations causes pollution of surface water, ground water and soil.

The following six impacts have more than one potential aspect:

- pollution of clean surface water by polluted surface run-off;
- surface water pollution due to release of pollutants from exposed waste rock on surface;
- ground water pollution by polluted mine service water;
- soil pollution due to release of pollutants from exposed waste rock on surface;
- pollution due to unauthorised and uncontrolled waste storage and/or disposal;
- biodiversity and/or habitat loss due to replacement of natural habitats (species, communities, ecosystems) by waste rock dumps and mining infrastructure.

For example, pollution of clean surface water by polluted surface run-off is caused by a lack of or insufficient arrangements to separate clean and polluted surface run-off water, as well as to collect, treat and recycle or dispose of polluted surface run-off water. Similarly,

pollution due to unauthorised and uncontrolled waste storage and/or disposal is caused by a lack of or insufficient arrangements to collect, treat and dispose of hazardous waste, to re-deploy, re-use or dispose of redundant equipment, as well as to dispose of radio-active waste and prevent or contain radio-active contamination.

#### **4.1.3. Significant environmental impacts and aspects of deep level gold mine shafts**

The evaluation of the environmental impacts of the activities, products and services at Shafts A and B resulted in the classification of 30 aspects that has or can have highly significant environmental impacts. The majority of these aspects were rated as highly significant for less than 20 percent of the impacts of identified generic activities. However, environmental aspects related to five environmental impacts were rated as highly significant for more than 25 percent of the impacts of the generic activities and less significant for others. These aspects are:

- a lack of or insufficient arrangements to minimise (reduce) consumption of potable and mine service water during operations;
- a lack of or insufficient arrangements to prevent or contain or clean up pollutant spillages during operations (related to two impacts);
- a lack of or insufficient arrangements to reduce, recycle, re-use and reclaim wastes; as well as
- a lack of or insufficient arrangements to collect, treat and dispose of hazardous waste.

In addition to the significant environmental aspects already discussed, a further four aspects were identified at both shafts that were subject to impacts from more than 50 percent of the identified activities. These could be split into the following two groups:

- aspects related to a small number of highly significant and a high percentage of environmental impacts rated as of medium significance, i.e. a lack of or insufficient arrangements to minimise electricity consumption during operations in order to minimise water and coal consumption, as well as gaseous emissions during electricity generation (related to three impacts); and
- aspects related to a small number of highly significant and numerous smaller environmental impacts, i.e. rated as of medium or low significance for more than 25 percent of the impacts of the generic activities. These include the following:
  - a lack of or insufficient arrangements to prevent or contain or clean up pollutant spillages during operations; and
  - a lack of or insufficient arrangements to re-deploy and/or re-use and/or dispose of redundant equipment.

#### **4.1.4. Business activities that could result in significant environmental impacts at deep level gold mine shafts**

The evaluation of the environmental impacts and aspects of the activities, products and services at both Shafts A and B also resulted in the identification of those generic activities that have or can have highly significant environmental aspects. According to the results of the evaluation, there are only three generic activities that do not have or cannot have highly significant environmental aspects. These are the:

- horizontal movement of people to and from shaft;
- loading of trams into cages; and
- storing of ore in reef bins.

The majority of the generic activities at both shafts were rated as highly significant for less than 20 percent of the aspects related to the impacts of these activities. However, for six of the generic activities, more than 25 percent of the aspects were rated as highly significant at Shaft B. These activities are:

- Dumping of waste rock on waste rock dump;
- Collection, settling, treatment, cooling and recycling of mine service water;
- Planning of surface infrastructure and services networks, as well as underground working and emergency facilities and service networks;
- Construction of surface infrastructure, equipment and services networks;
- Maintenance of waste rock dump;
- Maintenance of surface infrastructure, equipment and services networks.

At Shaft A, more than 25 percent of the aspects were rated as highly significant for a further two generic activities. These are the:

- provision of ventilation; and
- provision of electricity and lighting.

In addition to the activities mentioned above, another generic activity was identified at both shafts that was subject to impacts from more than 50 percent of the identified aspects, i.e. estate management.

## **5. Discussion**

It is generally acknowledged that the major environmental impacts associated with mining result from the nature of the mineral, the mining method employed and the mine residue deposits.

Gold in itself is one of the most stable substances, not capable of causing any environmental impacts. The environmental impacts normally associated with gold mining, therefore stems from the extraction of the ore and other minerals associated with the ore, as well as from the extraction process and the associated wastes. These essentially include the following:

- Gold occurs in minute quantities in ore bodies and thus has to be extracted in sophisticated plants using complex metallurgical processes. Once the few grains from each ton material mined have been extracted, the rest of the material is a waste product that creates the need to construct very large residue deposits on the surface. For low-grade gold deposits, tonnes of waste and high amounts of energy and water are required to produce a relatively small and simple gold object (Wells *et al.* 1992:353; MMSD Project 2002c:105).
- Pyrite is associated with all but alluvial gold-bearing ores. The pyrite that remains in underground mine areas, as well as waste rock dumps and mine residue deposits reacts chemically as a result of its exposure to air and water and causes a problem known as acid mine drainage or acid rock drainage (Wells *et al.* 1992:354).
- Uranium is also associated with gold-bearing ores in South Africa. As a result, uranium is the most important by-product of gold mining and has been exploited since 1952. This however causes radiation problems in South African gold mines. It also leads to the migration of dissolved uranium and other heavy metals from gold mines via groundwater into adjacent fluvial systems, creating off-site accumulations which may act as secondary sources of contamination (Winde & Van der Walt, in press).

Gold mining activities in South Africa are characterised by very deep and extensive underground workings. Due to the thin but extensive gold reefs often lying several kilometres beneath the earth's surface, the country's gold mining industry has to sink the deepest mine shafts in the world in order for miners to be able to reach and extract these reefs. Because of the difficulties associated with deep-level gold mining, gold mining is both labour and capital intensive. Massive amounts of capital is required for ventilation, cooling, hoisting, underground tunnelling and surface processing plants, which can all cause environmental impacts, while the mines are operated by large numbers of workers (Main, 1996: 13; Chamber of Mines of South Africa, 1998).

Potential pollutants involved in the extraction process primarily relate to substances used by the equipment involved in the process, as well as the explosives used. Equipment involved in this step of the mining process uses hydraulic fluid (containing glycol ethers), batteries (containing sulphuric acid, lead, antimony and arsenic) as well as lubricants and fuel (containing hydrocarbons). Fuels and oils typically contain such constituents as benzene, ethyl benzene, and toluene. Explosives (usually a mixture of ammonium nitrate and fuel oil) are used to break up the rock (US EPA, 1995:18).

In considering the environmental impacts of mining, it is important to take note of a number of factors. Firstly, unlike farming, where there is a choice of where and what to grow, or a large proportion of industrial activities where similar choices can be made, mining can only take place where minerals occur. The only choices to be considered when developing a mine comes in the consideration of mining methods, location of mine infrastructure and waste disposal sites, and the sources of power, water and raw materials needed for mining. Mitigation of environmental impacts by moving a mine to a more environmentally suitable site cannot therefore be considered (Wells *et al.* 1992:337; Ostensson, 1997:29).

Given the scale of commercial mining activities, it is not surprising that there is a considerable degree of environmental impact associated with most exploration, mining and mineral processing activities and negative impacts can be spread over large areas. The scale and nature of contemporary mines mean that they are almost always visible and they almost always change surrounding air and water quality. Though ideally, the minerals sector should not operate at the expense of the environment, in practice there is a balance to be struck if the decision to proceed with an operation is made. The challenge becomes how to optimise the trade-off between environmental damage and the potential benefits to local and national economies. This means that the impacts must be reduced so that mining is sufficiently compatible with surrounding land uses and preserve acceptable long-term uses of the site itself (EPA, 1995c:4; UNEP IE, 2000:5,6; MMSD Project, 2002b:26).

Another issue to bear in mind when considering the environmental impacts of mining is the total area of land that is affected and water consumed. Only a very small percentage of the land of South Africa is used for mining and only 2,7 percent of the country's water is used by the mining industry (which includes land and water used for processing the minerals). Although the total impact of mining on the South African environment is thus small compared to other sectors, it is important to remember that the magnitude of impact on each hectare or cubic metre of water used, may be higher than that of other sectors. This usually results in severe local impacts (Wells *et al.* 1992:338). Furthermore it must be realised that although the area or physical footprint occupied by the mine infrastructure is small in comparison with other land uses such as agriculture, the biological footprint of a mine may affect a much larger area (Chamber of Mines of South Africa, 2002:10).

The overall environmental impact of mining must also consider the economic and social impacts of a mining operation. Usually, these impacts are positive, especially the initial impacts. These include creating wealth and jobs, earning foreign exchange, providing housing, roads, power, water and other infrastructure in rural areas and providing training. The multiplier effect of every one rand spent on a mine is estimated at an injection of four

rand into the economy. The economic and social impacts can, however, also be negative due to mining being subject to global commodity failures, but also due to the temporary nature of mining. Adverse effects on local communities include job losses, as well as infrastructure decay due to a lack of maintenance after mine closure (Wells *et al.* 1992:337). The socio-economic impacts of mining did not, however, form part of this study.

Lastly, it must be kept in mind that being a true extractive industry, mining cannot be sustainable at one place, because the deposit is finite and is therefore eventually exhausted. The philosophy of optimal resource utilisation, which guides all responsible mining companies, means in practice that as much as possible of a mineral deposit must be extracted within the constraints due to safety, economic and environmental considerations (Wells *et al.* 1992:338).

Since the mining industry is important to the economies of many countries, and the mining process is unavoidably destructive, governments often choose to tolerate some level of environmental damage resulting from mining activities. Successful environmental management depends on recognising and avoiding or minimising environmental impacts. Many, but not all, of the environmental impacts of mining can be minimised through careful planning, monitoring and enforcement of clear, well-defined regulations. Managing the impacts of mining effectively requires dealing with unresolved issues of handling immense quantities of waste, developing ways on internalising the costs of acid drainage, improving both impact assessment and environmental management systems, and doing effective planning for mine closure (Anon., 1995; MMSD Project, 2002a:xvii).

## **6. Conclusions**

This study has identified significant environmental impacts and aspects of deep level gold mine shafts in South Africa. Some of the more important environmental impacts related to the activities, products and services at deep level gold mine shafts are water consumption and water pollution (surface and ground water), electricity consumption, soil pollution and waste management (more specifically hazardous and radio-active waste, as well as redundant equipment). Issues such as air pollution, as well as impacts on biodiversity, land use capability and topography seem to be of lesser importance.

These results are supported by various publications dealing with the environmental impacts of mining and mineral processing in general (UNEP, 1994:3.3; Anon., 1995; EPA, 1995a:10, EPA, 1995b:15-21; UNEP IE, 2000:5-7). A number of publications that deal with specific environmental issues, such as water or waste and also support the findings of this study in specifically describing the water related environmental impacts and problems facing the

South African gold mine shafts, include Evens (1989), Hart (1989), Funke (1990), Pulles (1992), Hearne & Bush (1996), Main (1996), Cowan & Cessford (2002) and Winde & Van der Walt (in press). Publications that address other environmental aspects of gold mine shafts such as electricity use, timber use, mining wastes (including waste rock dumps and hazardous residues, mining process pollution outputs, air pollution, surface subsidence as a result of dewatering and biodiversity impacts and support the findings of this study, include Funke (1990), Pulles (1992), Wells *et al.* (1992), UNEP (1994), Middleton (1996), Parsons & Hume (1997), Winde (2001), Wymer (2001), Chamber of Mines of South Africa (2002) and MMSD Project (2002d).

This study has also identified some generic business activities at deep level gold mine shafts that are potentially destructive and carry a high risk of causing significant negative environmental impacts at such shafts, such as the dumping of waste rock on a waste rock dump; collection, settling, treatment, cooling and recycling of mine service water; planning of surface infrastructure and services networks, as well as underground working and emergency facilities and service networks; construction of surface infrastructure, equipment and services networks; maintenance of waste rock dump; and maintenance of surface infrastructure, equipment and services networks.

In identifying some of the significant environmental impacts and aspects of deep level gold mine shafts, as well as some generic business activities that are potentially destructive and carry a high risk of causing significant negative environmental impacts, this study has contributed to a generic model for the initial environmental review process that precedes the development of an environmental management system at deep level gold mine shafts.

## References

- ANON. 1995. MINING SUPPORT PACKAGE. Metallic ores and minerals. July 14. 49 p.  
[Available on Internet:] <http://www.inece.org/PDFDocs/mining.pdf> [Date of use: 20 Jul. 1999].
- AUSTRALIA. Environment Protection Agency. 1995a. Environmental management systems. Best practice environmental management in mining. Commonwealth of Australia. 40 p.
- AUSTRALIA. Environment Protection Agency. 1995b. Environmental impact assessment. Best practice environmental management in mining. Commonwealth of Australia. 28 p.

- AUSTRALIA. Environment Protection Agency. 1995c. Mine planning for environment protection. Best practice environmental management in mining. Commonwealth of Australia. 28 p.
- CHAMBER OF MINES OF SOUTH AFRICA. 1997. Chapter 2: Environment and natural resources management - Annual report for 1996/97. Johannesburg: Chamber of Mines of South Africa. 82 p.
- CHAMBER OF MINES OF SOUTH AFRICA. 1998. The importance of gold mining to South Africa. [Available on Internet:] <http://www.bullion.org.za/bulza/educatn/nbgold98.htm> [Date of use: 16 Mar 1999]
- CHAMBER OF MINES OF SOUTH AFRICA. 2002. The contribution of the mining and minerals industry to sustainable development in South Africa. Johannesburg: Chamber of Mines of South Africa. 12 p.
- COWAN, J. & CESSFORD, F. 2002. Opportunities for assessing water conservation in the mining industry. Mine water management 2002. Supplement to *Résource* magazine in co-operation with the Department of Water Affairs and Forestry. Johannesburg: Shorten Publications. p. 16-17.
- EPA. See AUSTRALIA. Environment Protection Agency.
- EVENS, D.A. 1989. Water management programmes for mine service water in cooling systems. In: *Treatment and re-use of water in the mining and metallurgical industry*. Spécial publication series SP3. Johannesburg: South African Institute of Mining and Metallurgy. p. 19-37.
- FUGGLE, R. 1992. Environmental evaluation. (In Fuggle, R.F & Rabie, M.A., eds. *Environmental management in South Africa*. Cape Town: Juta & Co, Ltd. p. 762-780.
- FUNKE, J.W. 1990. The water requirements and pollution potential of South African gold and uranium mines. Report KV 9/90. Pretoria: Water Research Commission. 172 p.
- GILBERT, M.J. 1993. *Achieving Environmental Management Standards: A step-by-step guide to meeting BS 7750*. London: Pitman Publishing. 234 p.
- HEARNE, C.L. & BUSH, R.A.. 1996. Investigation into the impact of diffuse seepage from gold mines in the Klerksdorp region on water quality in the Vaal River. Phase I. Klerksdorp mine manager's association. Report No. CED/011/96. Johannesburg: Anglo American Corporation of South Africa Limited.
- HART, O.O. 1989. Water for the mines and mine water – a perspective. Keynote address: Treatment and re-use of water in the mining and metallurgical industry colloquium.

- In: Treatment and re-use of water in the mining and metallurgical industry. Special publication series SP3. Johannesburg: South African Institute of Mining and Metallurgy. p. 1-9.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996a. Environmental management systems - Specification with guidance for use. South African Standard. SABS ISO 14004:1996. South African Bureau of Standards. 14 p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1996b. Environmental management systems - General guidelines on principles, systems and supporting techniques: South African Standard. SABS ISO 14004:1996. South African Bureau of Standards. 31 p.
- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 2001. Environmental management – Environmental assessment of sites and organisations (EASO). South African Standard. SABS ISO 14015. South African Bureau of Standards. 19p.
- KUHRE, W.L. 1995. ISO 14001 Certification. Environmental management systems: A practical guide for preparing effective environmental management systems. New York: Prentice Hall Inc. 378 p.
- MAIN, T.R.N. 1996. Address of the Chief Executive, South African Chamber of Mines at the World Gold Conference. Venice, 24-25 June.
- MBENDI. 1997. South Africa - Mining industry profile. 27 Nov. 1997. [Available on Internet:] <http://www.mbendi.co.za/indy/ming/mingsa.html> [Date of use: 16 Mar. 1999]
- MEYER, T.C. & VAN DER WALT, I.J. In press. Implementing Environmental Management Systems to improve sustainable development in mining: 1. Towards a generic scope for deep level gold mine shafts in South Africa.
- MIDDLETON, J. 1996. Alternatives to CFCs. In: Case studies illustrating environmental practices in mining and metallurgical processes. First edition. UNEP Industry and Environment & International Council on Metals and the Environment. p. 40-41.
- MMSD PROJECT. See MINING, MINERALS & SUSTAINABLE DEVELOPMENT PROJECT.
- MMSD SOUTHERN AFRICA see MINING, MINERALS & SUSTAINABLE DEVELOPMENT SOUTHERN AFRICA.
- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002a. Executive summary. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. xiii-xxxiv.

- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002b. The minerals sector and sustainable development. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. 16-30.
- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002c. Case studies on minerals. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. 86-110.
- MINING, MINERALS AND SUSTAINABLE DEVELOPMENT PROJECT. 2002d. Mining, minerals and the environment. In: Breaking new ground – mining, minerals and sustainable development. London: Earthscan publications. p. 231-267.
- MINING, MINERALS & SUSTAINABLE DEVELOPMENT SOUTHERN AFRICA. 2002. Volume 1. The report of the regional MMSD process. Johannesburg: School of Mining Engineering, University of the Witwatersrand. 77p.
- OSTENSSON, O. 1997. Mining and the environment: the economic agenda. In: Mining and sustainable development. UNEP Industry and Environment October – December 1977. Paris: UNEP DTIE. p. 29-31.
- PARSONS, A.S. & HUME, H.R. 1997. The contribution of new technology to improved environmental performance in the mining industry. In: Mining and sustainable development. UNEP Industry and Environment October – December 1977. Paris: UNEP DTIE. p. 38-43.
- PULLES, W. 1992. Water pollution: its management and control in the South African gold mining industry. Journal of the Mine Ventilation Society of South Africa, 45(2):17-35.
- SOUTH AFRICA. Department of Environmental Affairs and Tourism. 1998. Guideline document on EIA regulations. Implementation of Sections 21 22 and 26 of the Environment Conservation Act. Pretoria: Government Printer. 57 p.
- STAPLETON, P.J., COONEY, A.M. & HIX, W.M. 1996. Environmental management systems: An implementation guide for small and medium-sized organisations. NSF International. Michigan: Ann Arbor. 160 p.
- UNEP. See UNITED NATIONS ENVIRONMENTAL PROGRAMME.
- UNEP IE. See UNITED NATIONS ENVIRONMENTAL PROGRAMME INDUSTRY AND ENVIRONMENT.
- UNITED NATIONS ENVIRONMENTAL PROGRAMME. 1994. Environmental management of mine sites. Training manual, first edition. United Nations Department for the Development Support and Management Services. Technical Report 30.

UNITED NATIONS ENVIRONMENTAL PROGRAMME INDUSTRY AND ENVIRONMENT. 2000. Mining – facts, figures and environment. In: Mining and sustainable development II – challenges and perspectives. UNEP Industry and Environment special issue 2000. Paris: UNEP DTIE. p. 4-8.

UNITED STATES. United States Environmental Protection Agency. 1995. Profile of the metal mining industry. EPA Office of compliance sector notebook project. EPA/310-R-95-008. Washington: Office of Enforcement and Compliance Assurance. 137 p. [Available on Internet:]

<http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/min.html> [Date of use: 13 Dec. 2002].

US EPA. See UNITED STATES.

VERSTER, J.J. & VAN LUITINGH, P. 1997. SA's mineral role within the SADC. Mining magazine, 177(1):48, Jul.

WELLS, J.D., VAN MEURS, L.H. & RABIE, M.A. 1992. Terrestrial minerals. (In Fuggle, R.F & Rabie, M.A., eds. Environmental management in South Africa. Cape Town: Juta & Co, Ltd. p. 337-379.

WEST G.A. & MANTA J.G. 1996. ISO 14001: An Executive Report. Rockville: Government Institutes Inc. 106 p.

WINDE, F. 2001. Slimes dams as source of uranium contamination of streams – the Koekemoer spruit (Klerksdorp gold field) as a case study. In Papers read at a Chamber of Mines conference on environmentally responsible mining in southern Africa held at Muldersdrift on 25 and 26 September 2001. [Available on Internet:] [http://www.bullion.org.za/Departments/Environment/Conference\\_on\\_Environmentally\\_Responsibile\\_mining\\_in\\_southern\\_Africa,\\_September\\_2001.pdf](http://www.bullion.org.za/Departments/Environment/Conference_on_Environmentally_Responsibile_mining_in_southern_Africa,_September_2001.pdf) [Date of use: 14 Apr. 2002]

WINDE, F & VAN DER WALT, I.J. In press. The significance of groundwater-stream interactions and fluctuating stream chemistry on waterborne uranium contamination of streams – a case study from a gold mining site in South Africa. Journal of Hydrology.

WYMER, D.G. 2001. The impact of gold mining on radioactivity in water and foodstuffs. In Papers read at a Chamber of Mines conference on environmentally responsible mining in southern Africa held at Muldersdrift on 25 and 26 September 2001. [Available on Internet:]

[http://www.bullion.org.za/Departments/Environment/Conference on Environmentally Responsible mining in southern Africa, September 2001.pdf](http://www.bullion.org.za/Departments/Environment/Conference_on_Environmentally_Responsible_mining_in_southern_Africa_September_2001.pdf) [Date of use: 14 Apr. 2002]

## **Chapter 4 - Conclusions**

The results of this study indicate that a generic scope can be developed to describe the business processes, physical boundaries and staff component of a deep level gold mine shaft, as many common aspects were found between the two shafts studied.

Five generic business processes were identified for deep level gold mine shafts, i.e. planning, development, mining (core & operational support), maintenance and administration. Forty-two generic activities were identified, of which eighteen were related to core mining activities, five to operational support activities, twelve to administrative support activities and the remaining seven to planning, development and maintenance activities. A number of facilities, required to perform the generic business processes and activities, were also identified. In terms of personnel, a number of generic functions were identified which are required to perform the generic business processes and activities at deep level gold mine shafts.

However, this study also clearly illustrated that there are certain non-generic issues at deep level gold mine shafts and sites that must be considered when determining the scope of any such shaft. These primarily relate to the facilities and personnel structure, which seem to be determined by site specific considerations, such as the local conditions at the site, time of initial development of the shaft, the age of the site, the stage in the mining life cycle of the shaft, as well as the preferences of individual mine managers.

This study has identified significant environmental impacts and aspects of deep level gold mine shafts in South Africa. Some of the more important environmental impacts related to the activities, products and services at deep level gold mine shafts are water consumption and water pollution (surface and ground water), electricity consumption, soil pollution and waste management (more specifically hazardous and radio-active waste, as well as redundant equipment). Issues such as air pollution, as well as impacts on biodiversity, land use capability and topography seem to be of lesser importance.

These results are supported by various publications dealing with the environmental impacts of mining and mineral processing in general. A number of publications that deal with specific environmental issues, such as water or waste, also support the findings of this study in describing the water related environmental impacts and problems facing the South African gold mine shafts, while others support the findings on other environmental aspects of gold mine shafts such as electricity use, timber use, mining wastes (including waste rock dumps

and hazardous residues, mining process pollution outputs, air pollution, surface subsidence as a result of dewatering and biodiversity impacts.

This study has also identified some generic business activities at deep level gold mine shafts that are potentially destructive and carry high risks of causing significant negative environmental impacts at such shafts, such as the dumping of waste rock on a waste rock dump; collection, settling, treatment, cooling and recycling of mine service water; planning of surface infrastructure and services networks, as well as underground working and emergency facilities and service networks; construction of surface infrastructure, equipment and services networks; maintenance of waste rock dump; and maintenance of surface infrastructure, equipment and services networks.

The initial review process is a critical first step, in the development and implementation of an ISO 14001 EMS, because the elements of the ISO 14001 EMS are in essence shaped and implemented around the organisation's environmental aspects and (potential or actual) environmental impacts. The generic model developed in this study could be used during the initial environmental review process to determine the scope, significant impacts and aspects, as well as business activities that are potentially destructive and carry a high risk of causing significant negative environmental impacts of any deep level gold mine shaft.

The results of the initial review process are used to establish objectives and targets that form the core of the environmental management programme and which is used as an organising framework to address environmental concerns through the allocation of resources, assignment of roles and responsibilities, ongoing evaluation of practices, procedures and processes and periodically reviewing progress towards meeting the objectives and targets.