An investigation of mine closure: gold mine case studies on the East Rand in South Africa

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Abstract

This research is on mines that struggle to obtain closure from the state departments. The closure process at the footprints of five Tailings Storage Facilities (TSFs) of a South African gold mine was investigated. They are situated in the Germiston, Brakpan, Springs and Nigel suburbs of the East Rand region of Johannesburg.

Very limited scientific research has been done in South Africa on the management of mine closure. The most recent performed research was completed at Coal mines and only one was at an underground gold mine. The history of the case studies at a surface gold mine revealed similar problems, as confirmed in previous research, during the interviews with mine management and the review of operational documents.

There is a whole array of causes giving rise to the struggle to obtain closure by a mine, that will be subsequently discussed. Major causes are the lack of estimation of closure costs and the lack of a proper Project Life Cycle (PLC) process for closure by mine management. Previous investigations indicated a general shortfall in estimated closure costs, mining operations that are not planned with closure in mind, closure objectives that are not set at all management levels, final land use after mine closure that is not defined properly, residual and latent impacts that are not dealt with, the post-closure period when the final impact will occur that is not defined and a proper risk assessment based on detailed information that is not properly done and communicated. Another cause is that the integrated process of making closure part of the Environmental Management Programme Report (EMPR) process is not followed. The result of not following the correct process is that mines do not obtain closure. Another reason why mines do not obtain closure is because of an underdeveloped mine infrastructure, e.g. tailings facilities, waste rock dumps, shafts and plants that are not constructed in an environmentally friendly way during the operational phases to facilitate closure. Therefore, these structures need to be changed in terms of their topography and growth medium to ensure an improvement in environmental parameters. This will assist in obtaining sustainability and final closure. Significantly more trust fund money than initially estimated during operations needs to be spent to ensure the above change.

Specific issues defined from the case studies were the adaptation of the administration of the closure process, the management of risks, especially the differences in opinions, the management of the mine life cycle for closure and involvement of the land owners and Interested and Affected Parties (I&APs).

This research was necessary because companies are uncertain and lack the competency to estimate and to correctly spend trust fund money in order to be sure of obtaining closure. This situation threatens the long-term survival of mining-companies by holding assets and profits back until closure is attained. The state departments also have to address the risks and have to rehabilitate the polluted mine sites if companies do not obtain closure.

A proper PLC to facilitate closure was compiled from the above-mentioned data. An important fact to bear in mind is that the activities within the life cycle depend on one another. Therefore, when one activity is disregarded or not properly performed, it will influence the outcome of the remaining activities.

The methodology of the research was as follows: Categories to evaluate the closure process of the selected case studies were determined from the project life cycle and the management principles of the literature review. Thereafter a questionnaire was developed from these categories. The questionnaire was subsequently used to guide interviews. After the interviews these categories and findings from the questionnaire were combined and summarised into key findings.

The key findings of the research were:

- The driving force behind obtaining closure must shift from the State Departments to the mining companies. They must realise there is an opportunity during the closure process to make money and to minimise their long-term liability. The mining company must thus drive the closure process to obtain environmental sustainability.
- The gold mines do have problems in terms of cost estimation and trust fund expenditure at their TSF footprints during the closure process. The reasons were a mismanagement of the closure process and making use of a limited information system to make decisions.
- A proper closure process does exist, but it can be improved to ensure all interested and affected parties have the same expectations from closure.
- There are many activities in the closure process flow diagram which were not properly attended to according to the case studies.
- A conceptual closure plan and a draft rehabilitation plan with broad objectives, policies and strategies with detailed descriptions were not compiled during the operational phase, because limited scientific monitoring information was gathered to do a proper risk assessment and some I&APs consultation was done mainly with the material and land owners on a one on one basis.

From these key findings the following recommendations could be formulated:

- Any mining operation should conduct a closure audit at least every second year and before mining activities change.
- A searchable record keeping system must be established to keep track of the closure life cycle development.
- Detailed conceptual and final closure plans need to capture the data from the audits and record keeping system.
- A communication forum with company management and environmental specialists needs to be established.

KEYWORDS: mine closure, trust fund, cost estimation, mine, gold mine, tailings facility, tailings facility footprint, slimes dam, rehabilitation, remediation, EMPR, closure plan, rehabilitation plan, environment, environmental management, sustainable, sustainability

Samevatting

Die navorsing handel oor myne wat sukkel om sluiting te verkry vanaf die staatsdepartemente. Die sluitingsproses van die voetspore van vyf slikopgaringsfasiliteite, van 'n Suid-Afrikaanse goudmyn is ondersoek. Hulle is geleë aan die Oos-Rand van Johannesburg in die woongebiede van Germiston, Brakpan, Springs en Nigel.

In Suid-Afrika is daar beperkte wetenskaplike navorsing gedoen rondom die bestuur van die sluiting van myne. Die mees resente navorsing is gedoen by Steenkoolmyne en daar is een studie gedoen by 'n ondergrondse goudmyn.

Gedurende die onderhoude met die mynbestuur en die hersiening van operasionele dokumente, is soortgelyke probleme uitgewys as in vorige navorsing en die geskiedenis van gevallestudies wat gedoen is by 'n oppervlakgoudmyn.

Daar is 'n wye verskeidenheid oorsake wat aanleiding gee tot die stryd om sluiting van myne te verkry, en dit sal volledig bespreek word. Hoofoorsake sluit die volgende in: onvoldoende beraming van sluitingskostes, 'n onvermoë van die mynbestuur om 'n behoorlike Projek Lewens Siklus proses vir sluiting te volg.

Vorige ondersoeke het aangedui dat daar 'n algemene tekort in sluitingsfondse is; mynbou aktiwiteite word beplan sonder om sluiting in ag te neem; sluitingsdoelwitte word nie op alle bestuursvlakke behoorlik gedefinieer nie; onderliggende en onbekende impakte wat moontlik nog kan plaasvind, word nie geïdentifiseer nie; die periode wat verloop na sluiting totdat die finale impak voorkom, word nie behoorlik gedefinieer nie en 'n gedetaileerde risiko analise wat op goeie inligting gebaseer is, word nie gedoen en gekommunikeer nie.

'n Verdere oorsaak is die feit dat die geïntegreerde proses om die sluitingsproses van mynbou aktiwiteite deel te maak van die Omgewings Bestuurs Program (OBP) nie plaasgevind het nie. Die resultaat daarvan om nie die korrekte sluitingsproses te volg nie, is dat myne nie kan sluit nie.

'n Ander rede waarom myne sukkel om te sluit, is die onderontwikkelde myninfrastruktuur, byvoorbeeld slikdam fasiliteite, uitskot rotshope, skagte en industriële aanlegte wat nie gebou is in 'n omgewingsvriendelike manier gedurende die operasionele fases nie en kan daarom nie sluiting fasiliteer nie.

Die strukture moet dus verander word in terme van hul helling en grondvrugbaarheid om te verseker dat omgewingseienskappe verbeter. Dit sal help om 'n volhoubare omgewing te skep en om finale sluiting te kry.

Dit was nodig om 'n beduidende groter bedrag trustfonds geld te spandeer as wat beraam is, om bogenoemde veranderings aan te bring.

Spesifieke sake wat in die gevallestudies gedefinieer is, was die aanpassing van die administrasie van die sluitingsproses, die bestuur van risiko's, veral die verskil van menings, die bestuur van die lewensiklus van die myn vir sluiting en die betrokkenheid van landeienaars en Belanghebbende en Geaffekteerde Partye (B&GP's).

Hierdie navorsing was nodig omdat maatskappye onseker is en nie oor die nodige ondervinding beskik om te begroot en die trustfonds geld oordeelkundig te benut, sodat die myn sluiting kan verkry nie. Die huidige situasie beïnvloed die langtermyn groei van myne deurdat eiendom en winste teruggehou word totdat die myn sluiting verkry. Die staatsdepartemente moet die risiko's aanspreek deur besoedelde myne te rehabiliteer as myne nie sluiting verkry nie.

'n Behoorlike Projek Lewensiklus om sluiting te fasiliteer was geformuleer vanaf die bostaande data. 'n Belangrike faktor wat in ag geneem moet word, is dat al die aktiwiteite van die lewensiklus van mekaar afhang. As een aktiwiteit uitgelaat word of nie behoorlik uitgevoer word nie, sal dit die uitkoms van die daaropvolgende aktiwiteite beïnvloed.

Die metode van navorsing was soos volg: kategorieë om die sluitingsproses van die steekproef studiegebiede te evalueer, was ontwikkel vanaf die projek lewensiklus en die bestuursbeginsels is ondersoek tydens die literatuurstudie. Hierna was 'n vraelys opgestel deur die kategorieë te gebruik. Hierdie kategorieë en bevindings van die vraelys is gekombineer en opgesom, nadat die onderhoude gevoer is, om hoofbevindings te vorm.

Die hoofbevindings van die navorsing was die volgende:

- Die motivering om sluiting te ontvang moet verskuif vanaf staatsdepartemente na die mynmaatskappye. Hulle moet besef dat daar geleenthede is gedurende die sluitingsproses om geld te maak en langtermyn verantwoordelikhede te verminder. Die mynmaatskappye moet dus die sluitingsproses bestuur om omgewingsvolhoubaarheid te verseker.
- Die goudmyne het probleme ten opsigte van kosteberaming vir hul sluitingsfonds en om die trustfondse te spandeer by die voetspoor slikdam fasiliteite gedurende die sluitingsproses. Die rede hiervoor was onvoldoende bestuur van die sluitingsproses en die gebruik van beperkte inligtingsisteme waarop hulle hul besluite gebaseer het.
- 'n Goeie sluitingsproses bestaan, maar kan verbeter word deur te verseker dat belanghebbende en geaffekteerde partye dieselfde verwagtinge het ten opsigte van sluiting.

- Die gevallestudie het aangetoon dat daar baie aktiwiteite is wat nie in die sluitingsproses vloeidiagram aangespreek is nie.
- Die konseptuele sluitingsplan en rehabilitasieplan, wat breë doelwitte en strategieë bevat, was nie volledig omskryf gedurende die operasionele fase nie. Te min wetenskaplike moniteringsinligting is ingesamel om 'n behoorlike ondersoek ten opsigte van risiko's te doen. Sommige konsultasies met belanghebbende en geaffekteerde partye is hoofsaaklik met materiële- en grondeienaars op 'n een tot een basis gedoen.

Vanuit hierdie hoofbevindings, is die volgende aanbevelings gemaak:

- Enige mynbou aktiwiteit moet ten minste elke tweede jaar 'n sluitingsoudit uitvoer, asook voordat mynbou aktiwiteite verander.
- 'n Ondersoekende rekordsisteem moet geskep word om tred te hou met die sluitings lewensiklus ontwikkeling.
- 'n Uiteensetting van konseptuele en finale sluitingsplanne is nodig om die data van die oudit en rekordhoudingsisteem in te sluit.
- 'n Forum vir kommunikasie tussen die maatskappybestuur en omgewingskundiges moet geskep word.

Sleutelwoorde: mynsluiting, trustfondse, kosteberaming, myn, goudmyn, slikdam fasiliteit, voetspoor slikdam fasiliteit, slikdam, rehabilitasie, remediasie, EMPR, sluitingsplan, rehabilitasieplan, omgewing, omgewingsbestuur, volhoubaar, volhoubaarheid

List of Abbreviations

BATNEEC	Best Available Technique Not Entailing Excessive Cost
BAT	Best Available Technology
B&GP's	Belanghebbende en Geaffekteerde Partye
CLC	Closure Life Cycle
CSIR	Council for Scientific and Industrial Research
CTF	Closure Trust Fund
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DWAF	Department of Water Affairs and Forestry
EMPR	Environmental Management Programme Report
I&APs	Interested and Affected Parties
MLC	*Mine Life Cycle*
MPRDA	Mineral and Petroleum Resources Development Act 28 of 2002
NEMA	National Environmental Management Act 107 of 1998
NWA	National Water Act 36 of 1998
OBP	Omgewings Bestuurs Program
PLC	Project Life Cycle
PRA	Probabilistic Risk Assessment
SFC	Sustainability for Closure
TSF	Tailings Storage Facility
TSFs	Tailings Storage Facilities

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Chapter 1 Introduction and Problem Statement

1.1 Introduction

Mine operations cannot occur without exercising an impact on the environment. Therefore a major driving force behind environmental management in the gold mining industry of South Africa is the government requirement of obtaining closure clearance from the State Departments. The environmental impacts often do not become apparent for decades following mine closure. Therefore the environmental requirement for closure is to provide evidence that pollution will not continue or is not a risk to the environment or humans. The general requirements for closure are to provide enough funds to implement all closure activities and to remediate residual or latent environmental pollution.

Part of this research is to investigate the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) and scrutinise the required closure certificate (South Africa, 2002). Research performed by Schoeman (1995); Packee (2004); Buthelezi (2004) and Koliasnikoff (1970) indicated that further research on the problems regarding mine closure is necessary. All of them focused on the closure process which entails the management of closure activities, the integration of closure activities into the operational phase and the environmental risk assessment for the closure phase. Very few mines obtained closure from the Department of Minerals and Energy (DME) to date and therefore this phenomenon emphasises the necessity of further research.

As part of the preparation for the process of obtaining closure, each mine creates a Closure Trust Fund (CTF) in which funds are set aside for the implementation of the required closure activities. Appropriate budgeting, including post-closure management of the CTF is necessary. In most cases the budget does not cater for all the aspects of rehabilitation and does not take cognisance of closure aspects (Schoeman, 1995:1). Currently there is uncertainty and a lack of competence with regard to how these funds must be determined and spent correctly in order to obtain closure, in view of the fact that gold mines have been largely unsuccessful in their attempts to obtain closure (Watson, 2006:493 and Drebenstedt, 2006:499). Experience with mines that have closed down, has been that administrative and financial issues have been responsible for most of the delays in winding up affairs of mines in the closing down stage (Koliasnikoff, 1970:1). During closure, the area that had suffered the impact of the mining activities must be restored to a sustained useable condition. This includes the minimisation of land utility capacity loss and conditions that are to the optimum benefit of society (Chamber of

Mines of South Africa, 2006:1 and Jones, 2006:475).

On the one hand, companies overreact by investing large amounts into ineffective financial resources. On the other hand, some mining companies believe that a mine closure will not be achieved, and thus attempt to bypass liabilities or to only make provision for liability claims while neglecting the long-term effects on the environment (Fourie, 2006:1095).

There is a belief referred to as "the myth of the walk away solution", stating that mine owners should be able to walk away from mine sites within 2 to 12 years after cessation of mining operations (Wiid, 2006:514). This is not necessarily the case, because not enough monitoring data could have been collected to indicate a trend in pollution reduction during this period.

The closure liabilities of existing disturbances and contamination associated with past actions by the mine need to be resolved. These difficulties need to be analysed and investigated in order to understand the requirements and difficulties. From these requirements and difficulties recommendations for closure need to be formulated and should also include disbursement of the trust funds.

The mining industry has seen the closure of a mine as a problem for the Department of Minerals and Energy. New legislation like the MPRDA, which include the polluter-pays principle, changed this view drastically (Sutton, 2007:353). The new legislation resulted in a legal non-compliance at most mines where closure aspects are not incorporated or updated in the Environmental Management Programme Report (EMPR) regularly. This non-conformance resulted in a legal and managerial non-compliance. One of the major implications for the mining industry was to achieve the optimum provision and expenditure of closure funds to obtain closure for their mines. Due to the fact that new legislation was only implemented during the last ten years, the subject of mine closure and specifically the process of estimation and expenditure of closure funds did not receive much attention in research.

1.2 Problem Statement

All the problems experienced during the closure phases are well-known. The reasons for the difficulties to obtain closure for these specific mine sites, need to be investigated in order to promote efficient, cost effective and timely mine closure, including trust in the restoration of the environment from the interested and affected parties after the optimal exploitation of reserves (Chamber of Mines of South Africa, 2006:3 and Schoeman, 1995:3).

1.3 Goals, aims and objectives of the study

This scientific research will focus on defining the problem of closure at the case study sites and analysing the difference between the Tailings Storage Facility (TSF) case study actions and the requirements and guidelines of the State Department. From this analysis, recommendations will be made to ensure that the activities implemented will result in closure.

Questions that need to be answered are, *inter alia*, the following:

1. What problems exist at the TSF footprints of gold mines during the closure process?
2. How can the closure process be evaluated?
3. In what way did the TSF footprint case studies give rise to the Project Life Cycle (PLC) process to obtain closure?
4. What were the differences between the activities of the investigated TSF footprint case study sites and the requirements of the closure process flow diagram and in what way can the investigation of these differences assist other closure projects?

The objectives include the following:

1. To perform a desktop study by reviewing appropriate literature on the problematic issues and constraints for the closure of TSF footprints at gold mines.
2. To formulate criteria by which the closure requirements, the history of the closure attempt, and internal obstacles can be evaluated.
3. To describe and analyse the history of five AngloGold Ashanti tailings storage facility footprints on the East Rand according to the process flow diagram with a view to closure.
4. To derive recommendations from the closure process flow diagram and the analysis of the case studies in order to improve and assist closure at other mines.

1.4 Methodology

Most of the selected case studies are in the final stages of reclaiming gold bearing tailings material from their footprints. From the original tailings facility, only small amounts of tailings material that need to be rehabilitated will remain after closure on each site. At some sites the decommissioning and closure phases are complete and the mines are in a monitoring and maintenance phase. Therefore all the selected case study sites have similarity in terms of their PLC, environmental impacts, rehabilitation technique, documentation control measurements and management strategies.

The main steps of the methodology analysing the history of these five tailings storage facility footprints on the East Rand in Johannesburg entails:

1. The selection and critical review of relevant literature.
2. Establishing evaluation criteria through the information obtained in interviews according to a questionnaire.
3. The investigation of the history of five tailings storage facility footprints.
4. The compilation of recommendations for closure.

The following sequence of events was followed during this research. After the review of research literature, categories (section 3.4) were defined to review the site-specific documents from the case study sites. From the two review processes, the evaluation criteria for closure (section 3.5.1) that influence the closure process were defined. Thereafter, the defined evaluation criteria as well as the objectives of this research (section 1.3) facilitated and ensured that the most appropriate questions for a questionnaire (Appendix 1) were formulated. These questions were asked during the interviews. The results (Chapter 4 and Appendix 2) obtained from the interviews were then used to evaluate the defined evaluation criteria (Chapter 5) and to provide the advantages and disadvantages in this process.

During the analyses the advantages and disadvantages were highlighted to ensure that the development of a proper guideline with recommendations would be possible. These recommendations and conclusions can then be used in future projects to ensure that mining areas obtain closure more readily. These recommendations should guide a mining project through the life cycle of the operation from pre-feasibility to ultimate site abandonment and closure (South Africa, 2005:14).

The mentioned evaluation criteria obtained from the closure factors are the main focus and directive force behind this research. Information from the five case study sites was used to analyse these evaluation criteria and to be able to evaluate and compare the case studies.

1.5 Chapter division

Chapter Two of this dissertation focuses on the literature review of the closure process and the closure cost estimation. This is followed by Chapter Three describing the methods followed during this investigation in terms of case study selection, case study documentation review, questionnaires and interviews. In Chapter Four the findings of the closure process followed during the selected gold TSF footprint case studies were indicated, where after Chapter Five discusses the findings of Chapter Four in more detail. The research is concluded in Chapter Six

with a summary and recommendations.

Chapter 2 Literature review of Mine Closure Requirements

2.1 Introduction

The problem statement requires the defining and evaluation of the reasons for the difficulty to obtain mine closure. The following findings, from scientific investigations, were seen to be relevant issues and constraints with regard to cost estimation for closure at gold mines and specifically the selected Tailings Storage Facility (TSF) footprint case studies. There is a general discussion of the process of managing mine closure, defining environmental influences and quantifying closure costs.

The history of previous attempts to obtain closure was analysed. The most recent research on various aspects of mine closure, including the final phase, Sustainability for Closure (SFC), quantification of the post-closure financial liability and the local level responses to mine closure will be evaluated (Schoeman, 1995:49; Packee, 2004:1; Buthelezi, 2004 and Koliasnikoff, 1970:84). Schoeman (1995) evaluated an underground coking coal mine of Iscor at Dannhauser and indicated in what way a holistic mine closure plan can be produced, in which the EMPR forms a vital component.

Packee (2004:14) investigated South African collieries and developed a procedure (post-closure impact appraisal procedure) that guides the mine owner through the initiating event search, event frequency quantification, and event magnitude quantification. Buthelezi (2004) investigated the local economic initiatives that have been undertaken in the three municipalities of North-Western Kwazulu Natal (Utrecht, Dundee and Dannhauser). Their response to the closures that have taken place in the mining industry of this region, which used to be one of the most prosperous mining regions of South Africa, was investigated.

The research by Koliasnikoff (1970) was performed thirty-eight years ago, but is still relevant, because he focused on the planning and management of closure for an underground South African Gold mine. Other significant issues investigated by Koliasnikoff (1970), that remain problematic even in the present day, include the financial constraints of closure, the fact that closure must be an integral part of the mining process, selection of the most cost-effective rehabilitation solutions to reduce the risk factors effectively, enforcement of the closure process through a top-down management sequence, and the initial partial development of a closure process flow diagram, which was expanded during this investigation.

Limited research on defining and resolving problematic issues regarding mine closure is available. Various library search engines were consulted to obtain the necessary reference

material on closure and specifically the management of the closure process. The scientific material was obtained from the NEXUS, Butterworths and Sabinet Online database systems. The websites of Department of Minerals and Energy (DME), Department of Water Affairs and Forestry (DWAF) and Council for Scientific and Industrial Research (CSIR) were accessed to obtain guidelines.

2.2 The life cycle and process flow diagram of closing a mine

Traditionally, closure has marked the end of the mine owners' financial involvement with the mine. Closure was defined as the point in time at which mining activities cease. Currently this is not the case and it now marks the beginning of the post-closure phase of mining operations. During this period, the defunct mine needs capital expenditure for monitoring, mitigation and maintenance without providing revenue generation.

One of the major issues facing the South African mining industry is the long-term financial implications of post-closure mines. Before mine owners can address the financial implications of the closed mine, the post-closure period must be defined (Packee, 2004:14).

The Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) is the leading legislation regulating environmental management on mines. Currently regulators in South Africa strive towards consolidating the regulation and legislation of environmental management for the industry in general. The problem hereof is that other industries do not necessarily have the same PLC during a closure phase. Although the closure process had always been part of the initial EMPR process, it was normally listed as a separate item, making it difficult to understand in what way it fits into the whole PLC. Therefore the closure process was seen as a separate process, distant from mining activities, a process to perform only once closing of a mine arose (Schoeman, 1995:1).

When mines started to reach the decommissioning and rehabilitation phases recently a better understanding of rehabilitation and monitoring costs could be made, resulting in a huge underestimation of the initial estimated closure costs. The estimated costs can still increase as an even better understanding of rehabilitation and closure costs is obtained.

Planning mining operations for closure, and thus avoiding high risks and minimising impacts, is considered the most cost-effective approach to closure (Sutton, 2007:361). The detailed planning for every aspect of closing down a gold mine is no easy or feasible task. An overarching strategy is necessary to cater for a professional approach to mine closure, therefore a formal management strategy with an appropriate organisational structure should be

put into place, and an appropriate set of goals should be developed (Schoeman, 1995:30). It is, however, of the utmost importance that objectives for the essential work that has to be performed should be set at all levels of management (Koliasnikoff, 1970:85 and Schoeman, 1995:16). Action plans with specific objectives in mind should also be compiled for lower management levels. These goals should form the criteria against which all actions and the possible outcomes of these actions are measured.

After determining the overall strategy and action plans with their objectives, procedures and controls need to be updated, customised for closure. The appropriate mandates should also be acquired from head office or top management, determining the measure of mine management involvement in activities such as communication, the selling of assets and negotiations with outside authorities on the utilisation of the remaining infrastructure and property (Schoeman, 1995:33).

Actions included in the closure life cycle are the alignment of the mining strategy, maintenance strategy to prevent losses, material management to optimise profits, the compilation of an asset register, the compilation of a property register to optimise the economic value of the final utilisation of the land and keeping the information systems intact to ensure historical information can be used in future when working towards the objectives.

A major objective of the closure life cycle is to determine in what way the mine company will address unemployment and poverty after closure, this objective will be a point of focus during Interested and Affected Parties (I&APs) consultations. In cases where there have been massive industrial closures, especially in rural mining towns, it would be unrealistic to expect that the municipalities are able to respond to the crises. In the well-resourced localities, especially the metropolitan areas, the mines manage to engage in larger projects geared towards attracting business investment.

The diversification of the economy should be a proactive rather than reactive initiative (for example to attract major industries to the area to ensure local economic development), which will ensure a solution to the socio-economic problem. Moreover, in the context of a closed down industry that has been providing employment to people, it is highly unlikely that new local economic development initiatives (small scale industries) will create substantial, direct employment for the masses of unemployed mine employees. Therefore the avenue of capacity building, amongst others training, must also be investigated. This enables people to engage in their own activities without expecting jobs to be created on their behalf (Buthelezi, 2004:207).

More research needs to be performed as regards to understand in what way these objectives must be defined in monetary terms and in what way a mine can save on these costs when better planning with regard to mining activities is done to assist with closure and reducing rehabilitation costs.

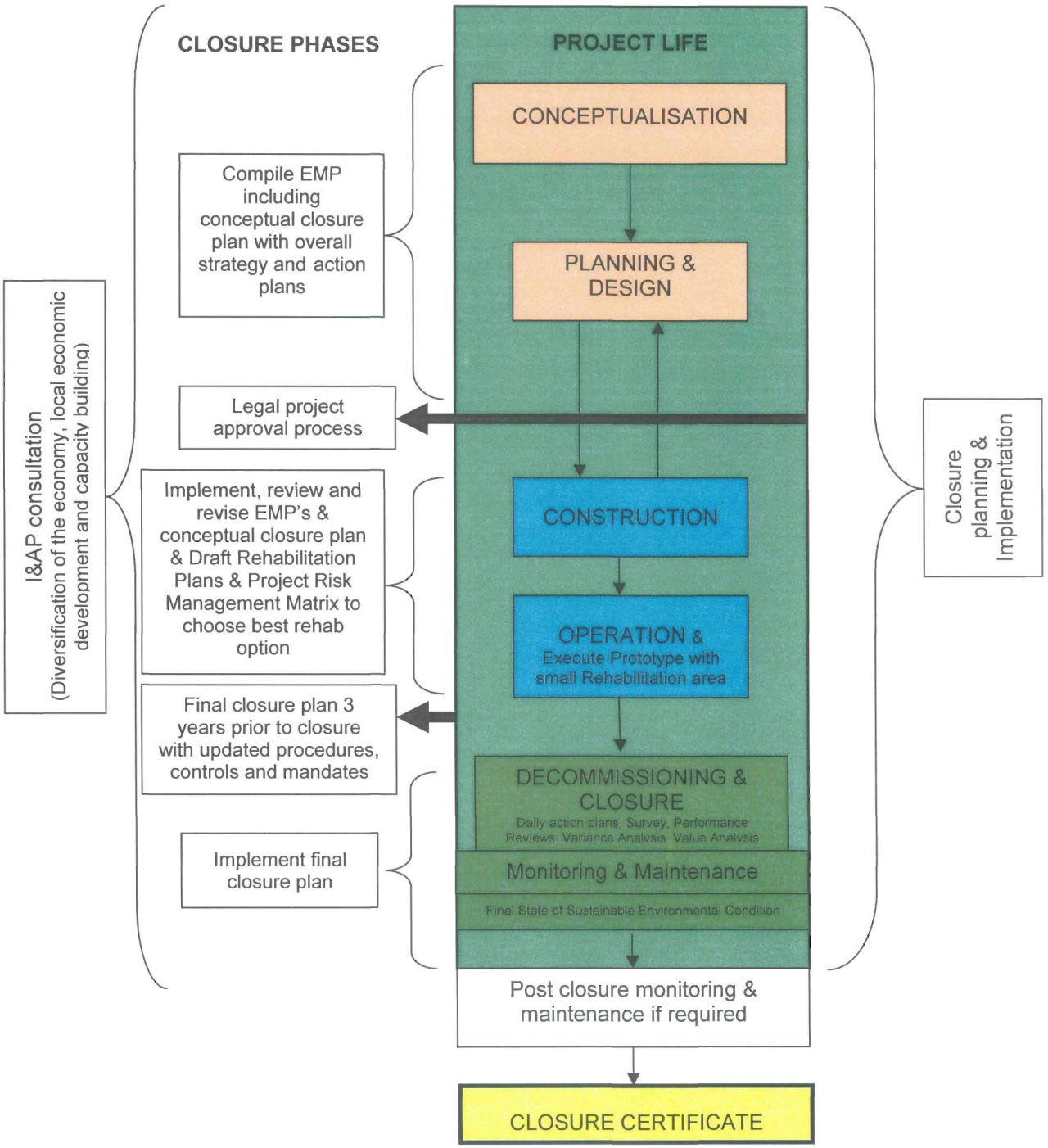

Figure 1: The Closure process during the conceptual design, planning design, construction activities, operational activities, decommissioning and monitoring phases (Fourie, 2006:1094)

As seen in Figure 1 the closure process of planning and implementation should form part of the total project life cycle. A review of pertinent South African environmental and mining legislation revealed divergent views as to the duration of the post-closure period. From the legislation it can be concluded that the post-closure period begins with closure and ends when the final impact occurs (Packee, 2004:14).

2.3 Methods used to define mine closure in financial terms

The Department of Minerals and Energy (DME) has a cost estimation guideline to determine a baseline cost for closure especially when a new mine starts, but it is also applicable to existing mines. In the DME guideline on financial provisioning for mine closure, gold and uranium processing waste has been defined as basic, salt producing waste (DME, 2005:17), which could result to the fact that the financial provisioning requirements for gold mine residue deposits are significantly underestimated. Regulations 56, 60 and 62 of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) require that residual and possible latent impacts are identified and quantified, without providing any practical solutions to these problems, making financial estimation difficult. Regulation 61 of the MPRDA Regulations requires closure objectives to be established at the outset of the project in order to guide project design, to develop and manage environmental impacts, to provide broad future land use objectives and to make it possible for closure costs to be estimated.

The quantum of financial provision must cover planned closure at the end of mine life, premature closure when unforeseen circumstances force the mine to stop mining and close the company, and post-closure monitoring and maintenance after the end of mine life. Closing down a gold mine must be done in the most efficient possible way and at the least possible cost (Koliasnikoff, 1970:86). The main challenges faced are therefore the determination of the extent of liability, the prediction of the latent impacts with the calculation of the amount required, and the acquirement of an agreement with the state departments. This task will challenge researchers in both non-market valuation and natural resources accounting (Sutton, 2007:357). This research investigates this challenge.

2.4 Standards of financial closure estimation

The current situation in which assets and profits are held back until closure is attained threatens the long-term survival of mining-companies. The fundamental issue that can resolve this problem to some extent is the maintenance of a mining industry that is as environment friendly as possible. One method to this extent that can be used is to protect the mine owner from the

long-term financial implications of post-closure care without transferring such costs incurred to the public sector (Packee, 2004:11). Minerals legislation in South Africa provides for the protection of the environment at mine closure, but contains some flaws and shortcomings regarding sustainability and specifically the mine closure process. While some shortcomings may enable mines to externalise impacts and costs, others could result in increased long-term liabilities and costs because appropriate measures were not taken, (Sutton, 2007:361) specifically during the planning and operational phases.

Important factors to consider in the set-up of a gold mine are the human, material and capital resources. These resources must be combined and incorporated at all levels of management in such a way that optimal productivity is achieved at all times (Koliasnikoff, 1970:84).

The financial valuation procedure of post-closure impact can consist of four tasks. 1) Identify events leading to environmental degradation, 2) quantify the frequency of the degradation event, 3) identify the magnitude of the degradation, and 4) identify measures required to mitigate the impact and perform engineering and environmental cost analyses. The identification of the mitigation options is site-specific and could not be generalised over the range of possible impacts. Similarly, cost estimation is site-specific and should be done in accordance with appropriate mine or project specific estimating guidelines (Packee, 2004:3).

To achieve a realistic quantum, the mine owner must examine all the potential impacts that could occur during the post-closure period and quantify their statistical likelihood of occurrence. Probabilistic Risk Assessment (PRA) is a procedure for quantifying the likelihood of occurrence. In order to utilise the PRA at a mine, the mine site must be broken down into subsystems and components.

The long-term behaviour of closed mines can be predicted from empirical and semi-empirical methods. Moreover the behaviour can be related to quantifiable environmental damage. The assessment procedure is comprehensive and repeatable, based on information available regarding the site. Two problems with this procedure are apparent immediately and both are related to effective risk communication. The first is an information management problem and the second is that of risk communication.

The first problem occurs because the closure risk assessment requires a tremendous amount of information. Although this seems to be a simple problem of data management, the problem is not related to the collecting and analysing process by technical specialists. This information is utilised for negotiating closure with regulatory officials and interested and affected parties. The mine owner must demonstrate that the site does not pose a threat to the environment and that the taxpayers' money to fund rehabilitation on the mine site happens through the government.

The scope of such an undertaking requires that the mine owner has a standardised assessment method that not only quantifies the risks, but also logically conveys the fact that the owner has performed an assessment of all potential problems. The owner is also required to effectively communicate the risks to the non-technical public. This is of significant importance when financial obligations are involved, because the negotiations devolve from "in what way was the assessment performed?" to complex technical issues of modelling and data representation.

The second issue is common to all risk-based procedures, namely that of effective risk communication. The problem is not limited to communication between technical experts and non-technical experts, but also includes interdisciplinary communication. Although two experts from different fields may agree on a quantitative failure probability, their perceptions of the risk may be quite different. Effective communication of risk is determined by the mine owner and his representatives. The communication of risk is a significant issue that must be addressed early in the risk assessment procedure (Packee, 2004:4).

The assumption with the assessment procedure is that the risk was considered negligible once the probability of occurrence became less than 1 event per 100 years. Other authors would rate these as 'low' or, in the case of a dam from 'negligible' to 'unsafe' occurrence, depending on potential impacts. The risk assessment procedure quantifies the probability and potential impacts that mines might have following closure.

A fundamental truth about a mine is that mineral extraction will eventually cease (Packee, 2004:3). The duration of the life of a mine is mainly determined by economic conditions beyond the control of the mine owner. Mineral extraction will cease when the value of the mineral commodity becomes less than the cost of extraction. The sooner a post-closure audit is performed, the sooner the mine owner can start setting aside funds to meet long-term liability requirements. Ideally, a post-closure environmental audit should be performed as part of the feasibility study. This would allow the mine owner to maximise the time value of money and minimise the 'out of pocket' capitalisation required to fund post-closure care.

For the purpose of this investigation, it is sufficient to recognise that the time value of money exists. The fact that money has an inherent 'earning power' implies that investment decisions can only be made if both the duration and the amount of investment have been quantified. In the case of post-closure site assessment, the duration of investment is the time that will elapse before an impact occurs while the value of the investment is the cost of mitigating that impact. Currently, there is no general applicable quantitative method for determining the time between mine closure and the onset of post-closure impacts or the magnitude of those impacts.

A generic closure procedure should involve; 1) mine residue identification, 2) failure modes,

effects and critical assessment, 3) impact consequence analysis, 4) calculation of annual financial risk, 5) calculation of post-closure fiscal risk, and 6) calculation of financial provision.

The failure mode entails the magnitude, the time-related probability and the effects of the failure on the system integrity. The magnitude of the failure will, to a large degree, determine the remediation method required to repair or mitigate the environmental consequences. Irrespective of location, the magnitude of the impact selects one remediation method over another. The scope of available remediation methods and the site specific nature of the impact, make general statements of "best remediation technology" impossible to implement with any degree of accuracy. Scientific literature provides many rehabilitation methods but can be limited for some mine polluted sites. The functional probability of a selected rehabilitation technology is determined evidence-based and it must prove to be applicable to other similar sites. This method of selecting proven technologies eliminates the scientific testing of processes and technologies at the mining house's expense. If possible, at least three remediation methods should be identified for a specific impact and an engineering cost analysis should be performed with site-specific economic data in mind. The selected method must meet the need (i.e. the method must rectify the environmental degradation) at the lowest possible cost. Using the guideline concepts like Best Available Technology (BAT), Best Available Technology Not Entailing Excessive Costs (BATNEEC), etc. becomes irrelevant as the remediation methods selected will have a proven track record and will have been selected based on engineering cost analysis (Packee, 2004:14).

2.5 The environmental importance of financial requirements on mine closure

Mine operations cannot occur without exercising an impact on the environment. The environmental impacts often do not become apparent for decades following mine closure. Mining environmental impacts can be divided into the following categories: degradation of the land surface (surface disruptions), degradation of the water quality and/ or quantity (mine impacted waters) and degradation of air quality (atmospheric impacts) (Packee, 2004:3).

Restoration and rehabilitation are dynamic processes that span long periods of time and therefore long-term objectives are necessary. Some degradation associated with mining is irreversible from an ecological perspective, within the span of a few to many generations. Even after a closure certificate has been granted by the DME, the provisions of other legislation, such as the National Environmental Management Act 107 of 1998 (NEMA) and the National Water Act 36 of 1998 (NWA), could still prevail in the event of undisclosed or latent environmental damage. The 'Polluter-Pays-Principle' contained in the NEMA indicates that anyone who

polluted or damaged the environment must pay for the restoration and damages brought about by third parties. This long-term liability does not depend on the time delay between when mining activities stopped and actual occurrence of the pollution started as long as the pollution can be correlated to the specific company. This legislation is the government's single greatest mandate for insuring environmental compliance and it represents the greatest threat to the bottom line of mining companies (Sutton, 2007:361).

A rehabilitated mine site is vulnerable to natural influences such as erosion, which can result in failure of the rehabilitated site. Therefore provision should be made that the site should not require active management following final rehabilitation. Realistically, when rehabilitation is not designed properly and the natural processes continue, the environmental controls like gradient of the topography and vegetation types, designed for mine rehabilitation, will begin to fail through erosion and dying vegetation. The transition state between the condition following rehabilitation and system failure is when mining's environmental effects occur (Packee, 2004:2).

In order to address residual and latent liabilities, gold-mining operations in South Africa must adopt a precautionary approach, and consider the following risks when determining financial provision: near certainty of contaminated water, near certainty of sulphate, chloride, metal and naturally occurring radioactive materials which contaminate soils and sediments, loss of biodiversity, potential bio-accumulation of pollutants in flora and fauna, potential for human disease as a result of exposure to wind-blown dust from Tailings Storage Facilities (TSFs) and potential for structural damage within dolomitic areas through seismic events and sink-hole formation (Sutton, 2007:354).

The following land uses, for example residential townships, edible crop production or livestock grazing are considered to be unsafe end-land uses for TSF footprints or areas within the aqueous or aerial zone of influence of TSFs and metallurgical plants. Description of the range of soft land-uses (industrial sites, lined landfills, graveyards, sewage sludge disposal, land farming, carbon sinks such as fibre, pharmaceutical and biofuel species) suitable for interim and end-land uses should be included in regulatory guidelines in order to support mining companies in their decisions and financial provisioning. Provision should also be made for environmental compensations for irreparable damage and/or irreversible loss of ecosystem services to be paid to affected parties and for trade-offs of devastated land for land in a better condition (Sutton, 2007:356).

2.6 The closure process of a mine

The main functions of a manager at any level are planning, organising, co-ordinating, leading

and controlling.

Planning is the mental process of thinking through what is desired and in what way it will be achieved, and begins with the establishment of objectives or statements of purpose. Strategic planning decisions of top management result in broad objectives and policies which mine management can use as guidelines for action in completing operations at a gold mine site. The first step in management planning is to analyse the various activities that have to be completed in order to accomplish the overall objectives. When setting objectives at top level, the manager must evaluate internal resources as well as constraints, threats, opportunities and challenges of the external environment. In addition to these there is little to guide the top manager except the mines needs and his values, creativity, drives, legislation, and rehabilitation technologies.

The responsible manager should also establish sub-objectives within the framework set by overall objectives, which will guide the activities of his own unit. These sub-objectives is more specific, more detailed and function as short-term planning (Koliasnikoff, 1970:85).

It is problematic for lower level management when top managers do not clearly define and communicate objectives, because then these objectives of top managers are not always relevant or practical to implement. Middle management does not have the authority, but takes the initiative by changing the objectives to suit the circumstances. Therefore original decisions of top managers become constraints at middle management level when the mine is near to closing down time.

2.7 Conclusion

The reality is that mineral extraction will eventually cease, therefore post-closure starts when all mining activities ceased and have a long-term financial implication. Closure must therefore be managed at all levels of management by utilising the correct mining strategy, organisational structures, goals, objectives, action plans, procedures, controls and mandates. The correct management system for closure can be obtained by keeping the necessary information systems intact and by communicating the risks to management, the legislator and Interested and Affected Parties (I&APs).

The phases of the Closure Life Cycle (CLC) as defined in the PLC should be conceptual closure plans, final closure plans and final implementation. These closure phases require a review and updating process which include all legislative and I&AP requirements. This review and updating process for closure activities are similar to the continual improvement process stipulated in the environmental management standard of ISO14001. A lack of such an environmental

management system is a contributing factor to the difficult mine closure process.

This planning process for closure is a mental process of thinking through what is desired and in what way it will be achieved. The determination of the extent of liability and the prediction of latent impacts is important in closure cost estimation. The main categories of impacts are surface disruptions, mine impacted waters and atmospheric impacts. The perceptions of the risks from these impacts have a major influence on how the closure process is managed. The selection of the remediation method to reduce the impacts must be proven on similar sites to obtain land in a better condition and should be based on engineering cost analysis with site-specific economic data.

The planning process of the CLC as defined from the investigated research will be used to evaluate the study areas in the next chapter.

Chapter 3 Data Gathering and Study Area

3.1 Introduction

The problem statement, "Difficulty to obtain closure for the selected study areas", need to be evaluated through investigated research performed and planning of the Closure Life Cycle (CLC). Reasons for the problems and difficulties that arise within the closure process and pose a threat to obtaining closure need to be evaluated.

This chapter contains site selection criteria for the case studies, description of the case studies, the documentation review methodology to record the information from the selected case studies and the interview process through a questionnaire.

The following sequence of events for data gathering was followed during this research:

1) Review research literature
2) Establish categories from the research literature
3) Review site-specific documents within the established categories
4) Define evaluation criteria for closure
5) Formulate the questionnaire from the evaluation criteria and research objectives
6) Conduct the interviews by using the questionnaire
7) Discuss the history of the case studies through the use of the evaluation criteria

3.2 Site selection method to determine the case study areas for this research

Very similar situations for TSF footprints on the east-rand and west-rand of Johannesburg exist. At AngloGold Ashanti there are more than fifty tailings facility footprints. All of them are in different stages of the Project Life Cycle (PLC). Most of them are in the final stages of reclaiming the gold bearing tailings material from the footprint. At some of them the decommissioning and closure phases are complete and they are in a monitoring and maintenance phase.

The closure application to the Department of Minerals and Energy (DME) was submitted for some of them to obtain a closure certificate. The five sites selected as case studies for this investigation were randomly selected within the following criteria. The case studies are mainly from the first group of sites which are awaiting closure. The reason why the sites could be

selected randomly was the fact that all of them have similarity in terms of their PLC, environmental impacts, rehabilitation technique, documentation control measures and management strategies.

3.3 The Five Case Studies

Gold mining in the West Rand and East Rand regions of Johannesburg started in the late 1800's and early 1900's. Therefore many gold mine tailings facilities were developed in these areas. As Johannesburg expanded residential and industrial areas developed around these tailings facilities. All five case study areas are located in the East Rand region of Johannesburg. They are all situated within industrial and residential areas of Germiston, Brakpan, Springs and Nigel suburbs (Appendix 3). Topographical surfaces of the case studies are relatively flat but slope gently to nearby perennial streams.

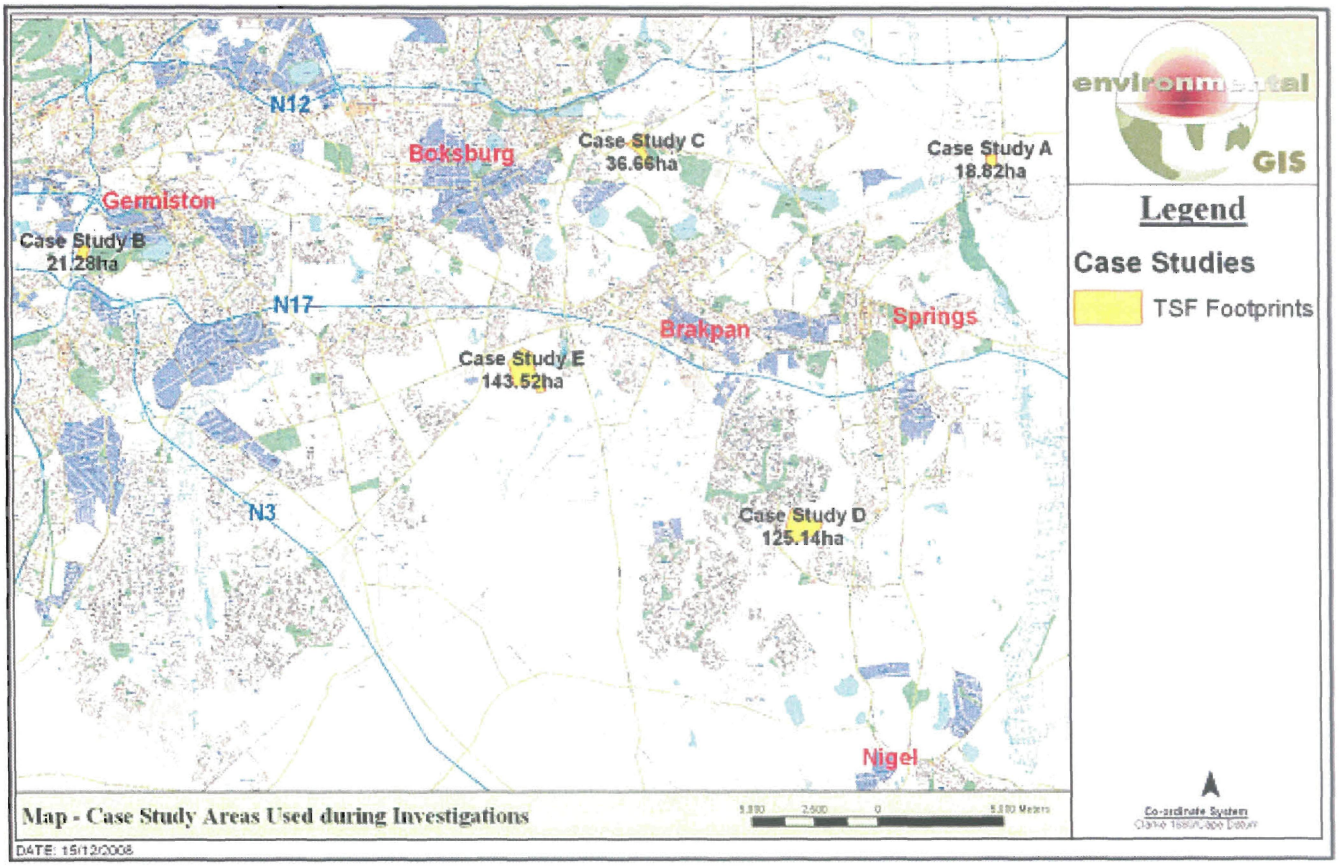

Figure 2: Location of case studies

3.3.1 Case study site A

This site is located amidst farming land in the Springs suburb. Residential areas are also located nearby. Most of the tailings material was removed and grass is currently being

established on the site. During the operational phase vegetation was only established on the completion of the earthworks. Vegetation was thus not established in smaller areas as the earthworks continued. At the moment the vegetation does not cover the whole site.

3.3.2 Case study site B

This site is located in an industrial area in the Germiston suburb next to the N12 highway. A perennial stream is situated West of this site. All tailings material was removed and grass is currently being established on the site. During the operational phase vegetation was only established on completion of the earthworks. Vegetation was thus not established in smaller areas as the earthworks continued. At the moment the vegetation does not cover the whole site.

3.3.3 Case study site C

This site is located in an industrial area in the Brakpan suburb. The material of another mine is located immediately West from this area. All tailings material was removed from this site and grass is currently being established on the site. During the operational phase vegetation was only established on the completion of the earthworks. Vegetation was thus not established in smaller areas as the earthworks continued.

3.3.4 Case study site D

This site is located in an informal settlement area in the Nigel suburb. A perennial stream is situated South of this site. Only part of the tailings facility was removed from the red soil surface. The tailings facility sides were sloped and grass is currently being established on the site. During the operational phase vegetation was only established on completion of the earthworks.

3.3.5 Case study site E

This site is located in an industrial area in the Boksburg suburb. A perennial stream is situated North of this site. The remaining tailings material on site was sloped and evaporation paddocks were constructed around it. Grass is currently establishing on the site.

3.4 Documentation review

The review of site-specific documents from the case study sites took place after the review of research literature has been completed and after defining categories influencing closure.

Current documents about the case studies were reviewed by reading them and selecting information relevant to this research. The relevant information was summarised for inclusion in this research. During the document review process the following information was evaluated: the extent of scientific and operational detail contained in the documents, the sequence of events, the relevancy of the detail on mine closure and closure costs specifically and the lack of detail required by legislation.

The results from the review of the site-specific documents of the case studies are summarised in Table 2. These results also assisted in the compilation of the evaluation criteria in Table 1. The following categories were determined from the closure life cycle captured in Figure 1 and the management principles summarised in section 2.7 of the literature review. The questionnaire (section 3.5) was developed from these categories (section 3.4). After the interviews, these categories and findings from the questionnaire were combined and summarised into internal and external factors (section 3.5.1) as discussed below.

During the review of scientific research literature, the following categories were identified to be directly or indirectly relevant to the closure process and to have influence on the closure process:

- Type of record-keeping system
  Information needs to be easily accessible to prevent the duplication of investigations and to make decisions quickly with limited uncertainties. The record-keeping system directly influences the closure process during the continuation of activities and ensures consistency.
- Method of communications
  The correct method of communicating (e-mail, telephone, meeting minutes, written order or written directive) needs to be followed to obtain the necessary reaction and to ensure that closure phases are completed. The closure process is therefore indirectly influenced by the methods of communication.
- List of decisions made
  Keeping track of decisions will prevent uncertainties and ensure better relationships with third parties. The closure process is therefore indirectly influenced by decisions made.
- List of commitments
  The commitments, especially to third parties, need to be listed and updated. This update is required frequently when responsible personnel changes. The closure process is

therefore indirectly influenced by the list of commitments.

- List of environmental incidents and failures

  Keeping track of failures and the cleanup of incidents will ensure that all sources of pollution are addressed. This will reduce the occurrence of latent or residual environmental impacts. The closure process is therefore directly influenced by environmental incidents and failure.

- Environmental risks

  The major environmental risks need to be identified and updated. The risks must be clearly defined to understand the problem and to determine the correct solution. The closure process is therefore directly influenced by environmental risks.

- Environmental descriptions and conditions

  A better understanding of the interaction between the environment and mining activities will ensure a better understanding of the influences on the environment. The closure process is therefore directly influenced by environmental descriptions and conditions.

- Environmental monitoring data

  Keeping track in the development of pollution plumes will indicate the magnitude of the problem. These monitoring data of the pollution plumes will directly influence the closure process to indicate progress towards closure.

- Mining plan details and changes

  Changes in the mining plan can alter the environmental impacts and subsequently the closure costs. Not keeping track of these changes can result in a shortage of closure funds. The closure process is therefore directly influenced by mining plan changes.

- Environmental Management Programme Report (EMPR) detail and updates

  The proper management of mining activities will reduce the environmental impacts as well as closure costs. The closure process is therefore directly influenced by the EMPR.

- Rehabilitation plans

  The rehabilitation plans must contain the details for the completion of each phase in the closure process. Without defining this detail the closure process is due to failure. The closure process is therefore directly influenced by rehabilitation plans.

- Exploration detail

  The exploration data will assist in the selection of the final rehabilitation method. The closure process is therefore indirectly influenced by the exploration detail.

- Detailed investigations or studies

  A proper process with goals and objectives for investigations is required to obtain valuable results for the closure process. The closure process is therefore indirectly influenced by detailed investigations.

- Scope for determining rehabilitation

  When the scope for determining rehabilitation is not properly defined, the actions of rehabilitation will not be implemented correctly and will not have the desired outcome on reducing environmental pollution. The closure process is therefore directly influenced by this scope.

- Budgets for rehabilitation

  Budgets and specifically budget cuts must not be a restriction during rehabilitation. The most appropriate rehabilitation method must be determined and cost estimated. These costs must then be included in the budget for a specific year and implemented without changing the budget. The closure process is therefore directly influenced by the budget.

- State Department meetings and communication

  The state departments give final closure for a mining site. They and the mining company need to be satisfied that the environmental liability is acceptable. Through these communications everyone must understand and have the same expectations regarding the acceptable environmental liability. The closure process is therefore directly influenced by the decisions of the State Department.

- Interested and Affected Parties (I&APs) meetings and communication

  Through these meetings everyone must understand and have the same expectations regarding the acceptable environmental liability. The closure process is therefore indirectly influenced by I&APs meetings and communication.

- Legal documents like contracts and general record keeping

  There are a number of binding legal documents like the EMPR, Closure Plans, and Contracts with owners. The commitments in these legal documents need to be synchronised to ensure a consistent closure process. The closure process is therefore directly influenced by the legal documentation.

- Usage of maps and photographs of these sites

  The mentioned photographic material can indicate the development of pollution plumes and magnitude of the problem. The sequence of photographic material over time will

indirectly influence the closure process to indicate progress towards closure.

The above categories contribute directly towards fulfilling the objectives of the research by indicating the possible constraints of closure. Major constraints are keeping track of decisions, focusing on significant environmental risks, solving these risks through a proper closure process and obtaining approval. These categories can thus indicate whether the history of the selected case studies followed the appropriate closure process.

3.5 Design of Questionnaire and Interviews

The categories influencing the closure process (section 3.4) as well as the objectives of this research (section 1.3) facilitated and ensured that the most appropriate questions were formulated from the background information (Chapter 2). These questions were asked during interviews between the author and five mine personnel who were actively involved with the planning and rehabilitation of the selected case studies. The layout of the questions was also done accordingly to prevent similar questions following each other.

A questionnaire was compiled and used to facilitate the interviews. During the interviews not only the exact answers for each question was obtained, but personal views, perceptions, operational methods and experiences were captured to add value to this research. These five interviews were regarded as sufficient because of the detailed method according to which the interviews were facilitated. The persons with whom the interviews were conducted were the only personnel who had daily experience with the case study sites on a long-term basis. Interviews with the authorities were considered, but all the officials were newly employed and not familiar with the case study areas to indicate a long-term trend. Only one interview with each person was held during which the issues for all the case studies were combined.

From the literature review the questions below were defined as issues, which need to be evaluated when defining the process of mine closure, determining the quantum of mine closure costs and understanding why mine closure was so difficult or impossible. Many of these issues do not have exact answers, but it must be determined whether they were taken into account. The appropriateness and effectiveness of the issues must also be evaluated for each specific situation.

- Was there a shortfall in estimated closure costs?
- Were mining operations planned with closure in mind?

- Is there an overall management strategy for closure?
- Do management mandates exist to address closure issues?
- Is there an appropriate organisational structure laid out?
- Are human, material and capital resources productively used?
- Are objectives set at all levels of management?
- Are appropriate interim and final land uses defined properly?
- Are broad objectives for future land use determined?
- In what way can residual and possible latent impacts be dealt with?
- Are there action plans for the closure process?
- Are procedures and controls updated?
- In what way can unemployment and poverty after closure be addressed?
- Was a post-closure audit performed?
- Was the post-closure period defined?
- When will the final impact occur?
- Is there enough information to do a proper probabilistic risk assessment of all potential problems?
- Were the risks properly communicated throughout all spheres of expertise, state departments and management?
- Were the risks properly understood?

Attached in Appendix 1 is a questionnaire in the closed ended format where respondents' answers are limited to a fixed set of responses. They are not only dichotomous questions where respondents answer with a "yes" or a "no", but they are designed as multiple choice questions in which respondents have five options from which to choose. This multi-choice questionnaire also includes space to give comments and additional detail to each question. These comments help to determine whether the respondents interpreted the questions correctly and provide the researcher with the opportunity to obtain additional information for this investigation.

All questions needed to be answered by choosing one of the following options; 1 for 1% – 10%, 2 for 11% to 30%, 3 for 31% to 50%, 4 for 51% to 75% and 5 for 76% to 100% or as indicated in

brackets. An uneven breakdown for the percentage selected of the five interval sections above is used to prevent a neutral outcome when only a yes or no answer is expected in the questionnaire. The ideal is thus to have a value of 5 (between 76% and 100%) for all the questions to facilitate an easy closure. The value of 5 will thus indicate that no or very few problems occurred and that all activities were completed as properly planned, therefore closure should easily be obtainable.

The questions used during the interview were grouped into questions of issues influencing the different internal or external closure factors. All the questions had to be answered for all the tailings facility footprints of the case studies. Each question was categorised under a specific internal or external factor as discussed in Chapters Four and Five. Some of the questions can be related to more than one factor. The major variances of internal and external factors, which require attention to obtain closure, are indicated on a graph to assist in the formulation of the observations and conclusions.

The first interview was the baseline test result and was held with a knowledgeable person out of the five persons on site who was actively involved with these case studies. This interview indicated that the questions were relevant and provided the required outcome.

3.5.1 Introduction to mine closure factors which summarises the findings from the interviews

During the investigation various external and internal factors were defined. Seven external and twelve internal factors were considered to be the main factors that influence closure. They are listed in the table below. The issues mentioned above, retrieved from the reviewed documents, were seen to be incorporated into these external and internal influences the company has on closure.

The relationship between main factors or influences on the closure process and the questions of the interviews (Appendix 1) are not necessarily directly correlated but in many instances indirectly correlated. They are as follows:

External	Relevant to Question No.	Internal	Relevant to Question No.
Political	32, 48	Personnel	9, 14, 19, 24, 26, 30
Affirmative Action	15, 48, 51, 53, 55	Management	6, 14, 24, 38, 56
Legislation	16, 17, 18, 20	Budget	10, 11, 13, 16, 20,

Factors

External	Relevant to Question No.	Internal	Relevant to Question No.
			22, 25, 28, 29, 36, 41, 47, 50, 54
Legislator	15, 42, 48, 51, 55	Risk Management	2, 3, 4, 5, 7, 10, 13,16, 18, 20, 23, 25, 27, 35, 37, 41, 43, 47, 49, 50
Mine Life Cycle	1, 3, 4, 7, 8, 21, 22, 28, 40	Corporate	6, 14, 16, 17, 32, 38, 40, 43, 47
Weather	4, 22	Resources	2, 3, 4, 8, 9, 11, 12, 17, 19, 20, 21, 22, 25, 28, 30, 37, 40, 46, 54
Land Owners and I&APs	2, 8, 16, 17, 18, 20, 31, 35, 49, 52	Investigations	2, 5, 8, 10, 12, 13, 16, 19, 23, 27, 28, 34, 40
		Objectives	2, 10, 16, 17, 20, 23, 24, 35, 46, 47, 49, 51, 52, 53, 56
		Monitoring	8, 19, 20, 23, 26, 27, 30, 34, 39, 45
		Administrative documents Current EMPR, Detailed investigations, Closure Plan, Exploration information.	1, 14, 19, 20, 26, 33, 44, 45, 49

External	Relevant to Question No.	Internal	Relevant to Question No.
		Opinions	18, 32, 43, 56
		Rehabilitation Techniques	4, 5, 7, 18, 22, 23, 27, 37, 39, 47, 54

Table 1: Internal and external mine-related factors to be investigated that can influence the capability of a mine to obtain closure.

The above factors entail the following, but are not limited to this description: political factors can be dependent on the change of the president of South Africa, the change of directors at the DME, the change in political party representative, etc; factors of weather can refer to events of high rainfall during earthworks or can refer to months following the establishment of vegetation, etc; personnel referred to are mainly mine employees or contractors who were involved on a daily basis; management referred to is mainly senior personnel who give direction on how the closure process must be implemented; corporate personnel give directives to senior personnel with goals and objectives; resources are not only enough skilled personnel, but can also include the availability of the correct equipment to keep track of decisions made, etc; objectives are the standards you set to achieve that need to be specific, measurable, achievable, relevant and time bound; opinions can be based on proven scientific facts or unproven knowledge with restrictions.

With these internal and external factors in mind, the history of the closure attempts of the case study areas and the difficulty of obtaining closure for them will be discussed in Chapter 5.

3.6 Conclusion

The process for the investigation was discussed in Chapter 3. Site selection criteria for the five case study sites were made according to the same closure life cycle phase they are at e.g. application for closure (section 3.2). Both the documentation review categories for the recorded information of the selected case studies, and the definition of questions were determined from the closure life cycle captured in Figure 1 and the management principles summarised in section 2.7 of the literature review. Following the interviews with five personnel, the documentation review categories and findings from the questionnaire were combined and summarised into internal and external factors (section 3.5.1). These internal and external factors will be presented in Chapter 4 and discussed in Chapter 5.

Chapter 4 Data Analysis

4.1 Introduction

The focus of this chapter will be to provide the results for the history of the case studies on mine closure determined during the interviews and documentation review. The findings from the interviews regarding internal and external factors are discussed in this chapter. The method of the calculation of these findings is also presented in more detail. The information from documentation reviewed on the case studies will be summarised. Finally, the Project Life Cycle (PLC) with its Closure Life Cycle (CLC) from Figure 1 is expanded to obtain a more complete PLC process in Figure 5.

4.2 Method of data gathering and analysis for internal and external factors

During the interviews with mine personnel the questionnaires were completed as described in section 3.5. Each question was given a value from one to five. The answers of the questions relevant to a specific factor (section 3.5.1) were added and the total divided by the number of relevant questions to obtain the mean. Thereafter the mean for the factor of each interview was added and divided by the number of interviews to obtain the final mean value used in the factor graphs below (see Appendix 2 for the data). For example the value 2,20 in Figure 3 on the Political factor was calculated as follows:

- Two questions, numbers 32 and 48 relate to this factor. The answers for questions 32 and 48 of interview one were 1 and 4, therefore the mean was calculated as follows: (1+4)/2 = **2,5**. The mean for interviews 2, 3 and 4 were respectively calculated; (1+4)/2 = **2,5**, (1+1)/2 = **1** , (2+5)/2 = **3,5** and (1+2)/2 = **1,5.**
- Thereafter the final result for each factor was calculated by adding the means of all the interviews. The calculation for the political factor was: (2,5+2,5+1+3,5+1,5)/5 = **2,20**.

For easier interpretation, the history for the case studies was divided between internal and external factors. These factors give direction to reasons leading to the difficulty of obtaining closure for these case study areas.

4.3 Problematic issues in terms of External Factors

The following graph indicates the external influences obtained from the interviews with major role players of the case studies. These influences on the history of the case studies as indicated below will be discussed in section 5.4.

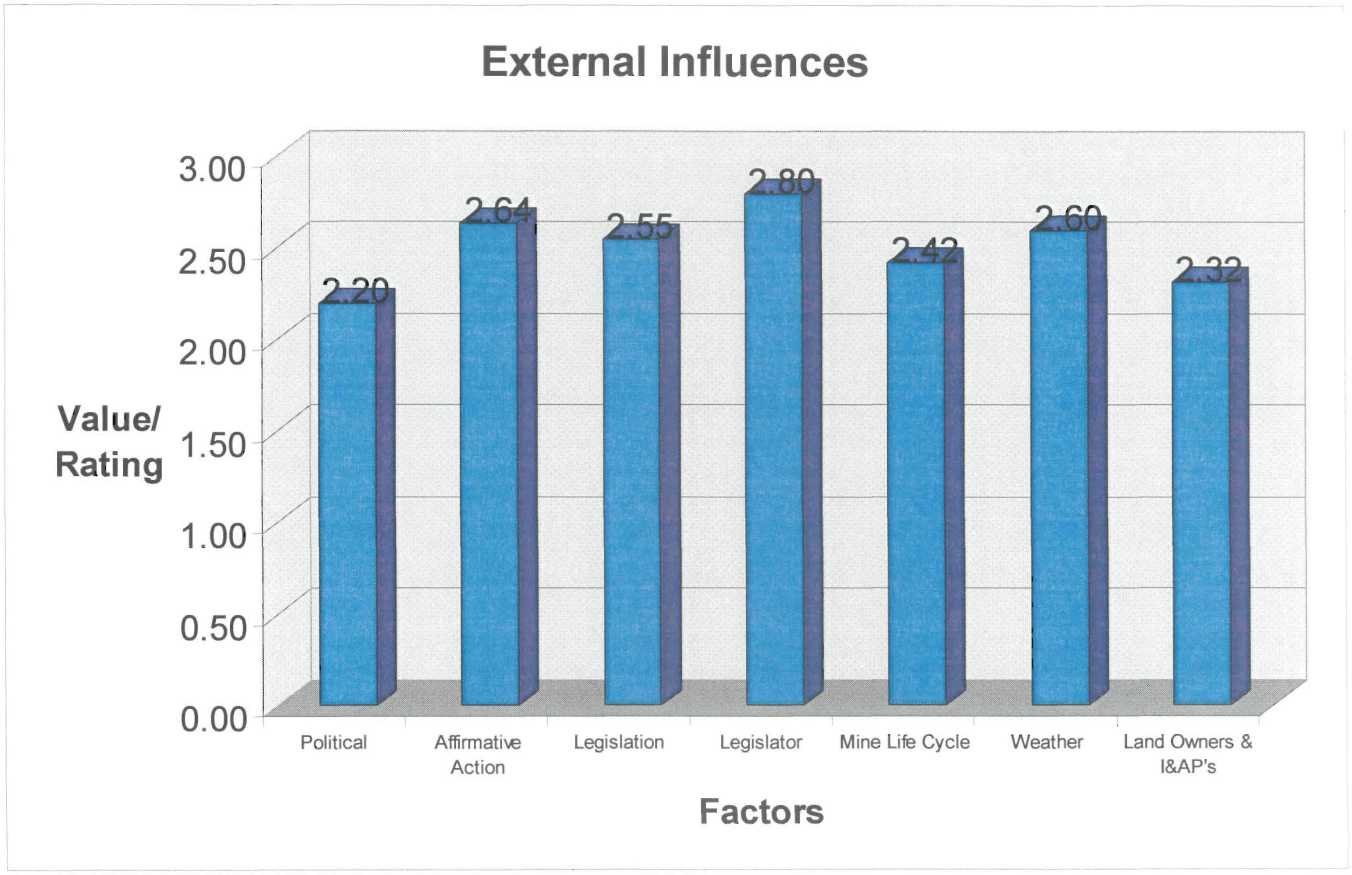

Figure 3: Results from the interviews that indicate the variation between external factors that can influence the capability of mines to obtain closure

As indicated in section 3.5 the most ideal values for facilitating an easy closure process are values of 5. As seen in Figure 3 all the values are lower than 3, an indication of a difficult closure process, specifically regarding the estimation and managing of closure costs. The managing of closure costs appears to be a major item in the Project Life Cycle (PLC) for closure and is influenced by all these factors. The influences that scored the highest in these case studies, which facilitate mine closure, are the legislator, affirmative action, weather conditions and legislation influences. External influences that need the most attention are political factors, land owners, Interested and Affected Parties (I&APs) and management of the mine life cycle.

4.4 Problematic issues in terms of Internal Factors

The following graph indicates the results of internal influences from the interviews with major role players. These influences on the history of the case studies as indicated below will be discussed in section 5.5.

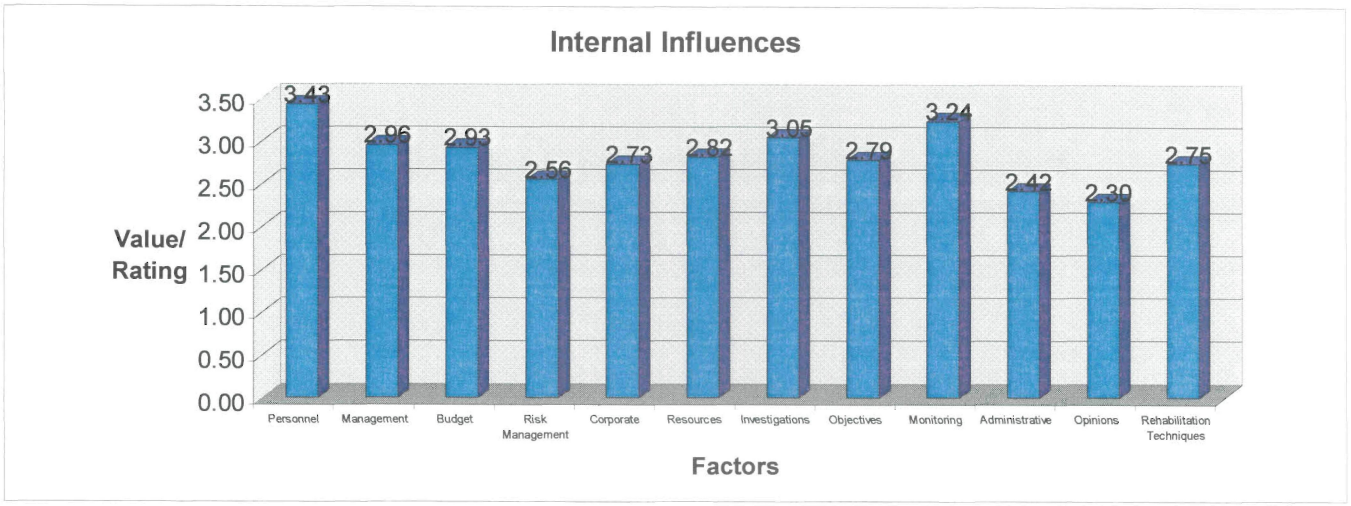

Figure 4: Results from the interviews that indicate the variation between internal factors that can influence the ability of mines to obtain closure

As seen in the above figure most of the values are less than 3, an indication of a difficult closure process, specifically regarding the estimation and managing of closure costs. The managing of closure costs appears to be a major item in the Project Life Cycle (PLC) for closure and is influenced by all these factors. The influences with the highest scores in these case studies, which facilitate mine closure, are the personnel, monitoring, investigations and management influences. Internal influences that need the most attention are differences in opinions, administration of the closure process and management of risk.

4.5 Operational documents of the case studies

The table below contains a summary of the findings from comparing the actual case study documents with the literature (Chapter 2 and section 4.1) as defined during this investigation. Only a description of each category is given. No scale of relevancy was determined.

No.	Documentation or information type	General Findings for all five case studies
1	Type of record keeping system (Digital or paper)	Mainly Paper without any index system. No transfer was made to digital format. Only new documentation was kept digitally but no index system was made for them.
2	Normal communications (e-mails)	No easily available records exist except for the minutes of meetings.
3	List of decisions made	No easily available records exist which summarise the decisions.
4	List of commitments	No easily available records summarise the current commitments. They are included in general documents like the Environmental Management Programme Report (EMPR), etc.
5	List of environmental incidents and failures	No easily available records exist. An ISO 14001 system was established for all TSF footprints just before this investigation.

No.	Documentation or information type	General Findings for all five case studies
6	Environmental risks	Contained in detailed investigation documents but not summarised to form an overall picture of a specific site.
7	Environmental descriptions/ conditions	Some site-specific environmental conditions were examined for these case studies.
8	Environmental monitoring data	The environmental information does not quantify the environmental condition in detail for all environmental parameters. The parameters defined are only for radiation clearance and soil fertility for the agricultural land use of these sites. Ground and surface water quality was only defined for one of the five case studies, which also contained limited results.
9	Mining plan details and changes	No mine plans could be obtained during this investigation. Most of them are digitally available but are without any description of changes.
10	EMP detail and updates	The first EMPR was submitted in 1993 and was updated four times. The EMPR contain information in general for all the Tailings Storage Facilities (TSFs) footprints of the mining operation. It contains limited site-specific environmental or rehabilitation information for each footprint area.
11	Rehabilitation plans	The EMPR was seen to be sufficient, therefore no rehabilitation plan was compiled for these case studies.
12	Exploration detail - Gold, uranium and sulphur content	The results indicated the pH, gold content and plant requirements for lime and cyanide application. No other environmental parameters were measured.
13	Detail investigations or studies	Very limited detail for these case studies could be found. Only the soil fertility for agricultural land use of one of the case studies could be found.
14	Scope of work for rehabilitation	No scope of work could be found.
15	Budgets for rehabilitation	The memorandum on the profitability of each dump did not exclusively indicate rehabilitation costs, but some of these costs were included in the operational cost part and thus used for operational activities. The reason for this was that the whole project was seen as a rehabilitation project with the extraction of gold as a bonus.
16	State Department communication and meetings	The minutes of meetings are available. Only operating sites were discussed and not all the sites each time.
17	I&APs meetings	Some minutes of the meetings are available. Operational constraints were discussed more than environmental issues.
18	I&APs communication	Very limited information is available. Some letters for two of the case studies are available.
19	Legal documents e.g. contracts	A legal contract is available for each case study to obtain the tailings material for the extraction of gold. The company does not own any of the land and was also not the original creator of the TSFs. Within the legal contracts the company took responsibility at most of the case studies for all environmental and rehabilitation liabilities. The end land-use was not discussed explicitly. For most of the case studies the area of responsibility for these servitudes are not legally clear. Most of the servitudes are not digitally available on a map.
20	Maps and Photos of area	Maps and photos are available for each case study but are incorporated within the data of all the other footprint areas that is the responsibility of the mining company.

Table 2: Findings obtained during review of the operational documentation of the case studies

The above categories are all integrated into the PLC. The managing of closure costs appears to be a major item in the PLC for closure and is influenced directly or indirectly by all the above categories.

4.6 Detail Project Life Cycle

Below is an altered PLC process diagram indicating the input of cost estimation and in what way the closure process is influenced by financial provision. This cost item is transferred from the history of the case studies in terms of internal and external factors and operational documents.

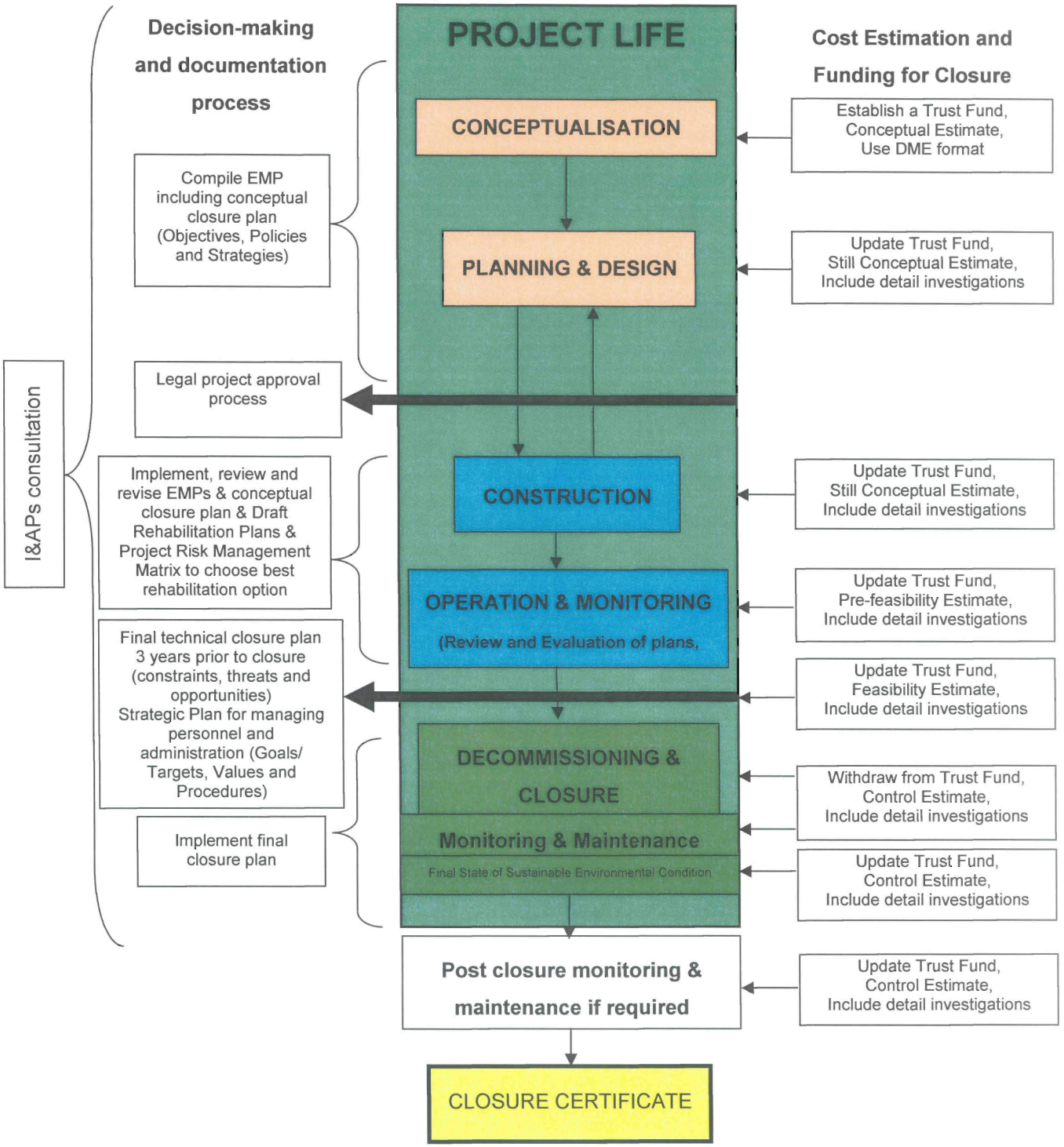

Figure 5: The Closure process as derived from Figure 1, which indicates the financial requirements and influences on cost estimation during the planning and implementation phases

4.7 Conclusion

The results of external and internal factors indicated a difficult closure process. External influences that need the most attention are the political factors, land ownership, I&APs and management of the mine life cycle influences. Internal influences that need the most attention are differences in opinions, administration of the closure process and management of risk influences. The same tendency was found with the case study documentation reviewed especially in terms of administration of the closure process and specifically the method implemented for keeping records, which is an important factor with regard to decisions and commitments made to third parties. A single overview of the environmental risk was not properly constructed (tracking of incidents, monitoring data and legal documents) at these case studies to prevent differences in opinions. Therefore the management of risk was not done on a consequent basis. Changes in the mining plan were also not recorded properly and therefore limited changes were made to the environmental risk. These findings as well as the findings from the literature will be discussed in more detail in Chapter 5.

Chapter 5 Discussion of Key Constraints for Mine Closure

5.1 Introduction

A few factors of concern were raised during the compilation of data in Chapter 4. All the data from Chapter 4 (Figure 3, Figure 4 and Table 2) will be discussed in this chapter. The most critical data will be emphasised.

The relationship between the factors indicating why it is so difficult to obtain closure for these specific study areas and the first research question, *i.e.* "What problems do gold mines have at their Tailings Storage Facility (TSF) footprints during the closure process?" (section 1.3) needs to be discussed. The fourth research question would also need further attention as it pertains to indications of differences between the activities of the TSF footprint case studies and the closure process flow diagram.

5.2 The influence of the research data on closure costs (cost estimation and expenditure)

The external factors (Table 1): political, affirmative action, legislation and legislator, influence the cost estimation and expenditure when their requirements change in terms of new legislation, as was the case when environmentally specific legislation was introduced during the life cycle of these case studies. The influences of the Mine Life Cycle (MLC) external factors on closure costs are not properly defined. The subsequent closure phases will thus delay the closure process, which will result in an increase of the original estimated costs. The influence of weather will delay the closure process further and change the environmental impacts and ultimately the closure costs. When land owners and Interested and Affected Parties (I&APs) are not satisfied with the rehabilitated land with its new land use properties they will delay the closure process and this can result in significant increases of rehabilitation costs to ensure the committed land properties.

The change in personnel, management strategies, corporate mandates and resources (internal factors from Table 1) can influence closure costs significantly if proper control of decisions and commitments to state departments and I&APs are not evident. When the budget is based on objectives and targets of rehabilitation techniques from poorly defined risk management strategies, which originate from limited investigations and monitoring data, the closure costs will increase significantly. Therefore keeping track of all these changes need to be administrated and documented properly to limit the influence on closure costs. Therefore these specific

factors will be discussed in more detail in this chapter to determine in what way they can be managed optimally to reduce closure costs.

5.3 Discussion of cost estimation influences on mine closure

One of the findings revealed during the interviews is that there was an underestimation of estimated closure costs for these case studies. This underestimation created huge pressure on the expenditure of the company because most of the closure costs had been met with operational funds and additional funds were also transferred to the Closure Trust Fund (CTF) to ensure sufficient funds would be available once the operations had stopped. Based on this the overall management strategy for closure can be regarded as inadequate.

During operations the management of closure as well as the estimation of closure costs were not always properly done, because when operations ceased tailings material removal from these sites a proper post-closure audit was not performed so as to evaluate the consequences that would follow in the wake of ending the operations. The estimated closure costs were not updated properly by taking all the closure activities into account. Also contributing towards the lack of the identification of all closure activities was the fact that there was not enough information to do a proper probabilistic risk assessment of all potential problems. The potential problems partially stemmed from the fact that measures determining in what way to deal with residual and possible latent impacts were not determined. By not having all the risks properly defined, the risks could not be properly communicated to all spheres of expertise, state departments and management. Therefore the risks were not properly understood, especially the risk of the post-closure period, which is only complete once the final impact occurs.

The prediction was that the interim and final land use will be for grazing, without defining and understanding the risks associated with this land use. Therefore broad future land use objectives for all levels of management were based on unknown risks.

The action plans, procedures and controls for the closure process were based on these unknown risks.

The management mandates pertaining to ways and means of addressing closure issues, the lay-out of an appropriate organisational structure, the productive use of human, material and capital resources and addressing unemployment and poverty once closure is reached, have to be performed satisfactory to a certain degree.

5.4 Discussion of problematic issues in terms of External Factors

The normal day to day political factors (rating of 2.2 in Figure 3) indicating who the president of the country is or who the leaders of the local political parties are, do not directly influence closure as such, but they normally generalise the mining industry as major and long-term environmental polluters that lack preventative measures and proper rehabilitation activities. Due to this generalisation it is even more difficult for one company that implemented proper rehabilitation activities to motivate and indicate to a very sceptical political party a reduction in pollution and thus an improvement in environmental performance.

During the initial listing of these factors the influences of affirmative action and the legislator were combined for earlier discussions. In this investigation the legislator is seen as the legislator representative and/or head of department for each government department. They are thus seen as the people who need to make sure that legislation requirements are thoroughly interpreted and correctly implemented. Therefore they must have a proper understanding of the activity, in this instance the tailings facility footprints of the mine and in what way the legislation has an impact on it in terms of obtaining closure. The legislator who is responsible for a bigger regional area should be consistent in terms of decisions made between different mining companies with adjacent tailings facility footprints within this East Rand region of South Africa. Different departments have different mandates and legislation to implement therefore an integrated process must be followed due to the integration of different environmental factors.

Changes in the legislation also result in a change of state departments. For the specific case studies legislators met on a quarterly basis with mine management. They did not necessarily focus on all the tailings footprints, but only on those in which the mine was actively busy to mine or rehabilitate. There was thus not a continual tracking of activities on each individual footprint, which made the decision-making methodology very difficult. Role players of the major state departments, Department Minerals and Energy and Department Water Affairs and Forestry, did attend most of the meetings with mine management. A major shortcoming was the fact that the Department of Environmental Affairs and Tourism (DEAT) and the National Nuclear Regulator had been invited but were very seldom present. Their absence created problems regarding closure, especially in determining land use types, because the location of these tailings footprints was inside major developing areas of the city.

During the early days of mining in these selected tailings footprints, very little environmental legislation existed. The State Department representatives did not focus on environmental issues before the 1900s when the legislation changed. When the focus changed in terms of environmental legislation, the representatives of the State Departments also changed often,

which resulted in an inconsistent decision-making process. Due to the continual change of representatives, every person needs training regarding these tailings facility footprints and the relative legislation. Not only the training of representatives, but also the familiarisation of the sites is very time consuming. Even when they obtained the necessary knowledge, they did not have enough experience to add value to the decision-making process in terms of the required long-term activities and objectives, which facilitate closure.

There were also changes in terms of the working relations between different state departments and state departments' objectives and responsibilities. Because mining was performed over an extended period, these changes did influence the requirements for closure, and difficulties and problems surfaced as closure planning and closure processes constantly had to adapt to accommodate such changes. As legislation changed over time the detail thereof and guidelines also changed over time, fortunately for the better, especially as far as guidelines are concerned. It could definitely be observed from the activities of different mining companies with similar tailings facility footprint sites adjacent or near to each other within the same East Rand region, that those that did not have similar guidance or directives from the state department representative when the work commenced, suffered a disadvantage in this respect. But this could also have been the result of mining companies that were testing the state department representatives to the limit.

5.4.1 Affirmative Action (rating of 2.64 in Figure 3) should not have a negative effect on the closure process when implemented correctly. The closure process will be influenced when unqualified personnel are appointed to do the rehabilitation work and to implement the closure process. This influence on the closure process can be overcome by using qualified specialists. The unnecessary use of qualified specialists will result in higher closure costs, which is a risk to closure. Affirmative action includes, *inter alia*, the following consequences: The state department representatives are reluctant to accept responsibility to indicate direction for closure even when qualified specialists are involved, a change of legislator representatives in state departments on a regular basis and a set of ongoing changes in practice.

5.4.2 Legislation (rating of 2.55 in Figure 3) did change significantly over time to ensure a better closure process. This, however, did not ensure an increased number of closure approvals. Legislation and or better supporting guidelines should thus still be improved to facilitate the closure process. Not only legislation, but also corporate governance

decisions, should be redirected to assist with closure of mining sites. The general perception that mines will have difficulty to receive closure can be addressed significantly through proper corporate governance.

5.4.3 The mine life cycle (rating of 2.42 in Figure 3) generally remained standard whether detail phases like planning, exploration, construction, operations, maintenance, decommissioning and closure (Fourie, 2006:1086) are removed or added. The bottom line is that closure or post-closure with a stable environment must always remain the final goal of the mine life cycle therefore closure needs to be planned and implemented throughout the mine life cycle.

5.4.4 Weather (rating of 2.6 in Figure 3) conditions, especially high rainfall years during rehabilitation implementation, may result in additional environmental impacts not necessarily included with the risk assessments, and may thus result in higher rehabilitation costs. The normal practice is to implement rehabilitation activities during the dry months of the year but it is not always possible. When this is not possible weather conditions need to be included in the risk assessment, and rehabilitation activities must be implemented according to the findings.

5.4.5 Requirements and expectations from land owners and I&APs (rating of 2.32 in Figure 3) must be incorporated during mining activities where after it must automatically flow into the closure process. The intensity of their involvement will increase especially if they own the land. In cases where there is a third party that owns the material to be mined, but that is not the land owner then the third party must also be involved with the I&APs process. This process is a very delicate process to manage especially when conflict situations occur. I&APs need to be involved continually during the whole mine life cycle and not only for a specific project or phase of the mine life cycle. This will ensure that all stakeholders are updated with changes to commitments, which may influence them. These changes need to be confirmed in writing especially when a legal contract comes into play and has to be updated.

5.5 Discussion of problematic issues in terms of Internal Factors

Various internal factors (Table 1) can influence the closure process or the possibility of obtaining a closure certificate. Internal factors that can influence closure are difficult to qualify or even to quantify as far as the magnitude of the influence is concerned. This influence was defined in Figure 4 and the significance described in section 3.5. The factors that showed the

highest prevalence according to the responses were differences in opinions (rating of 2.3), administration of the closure process (rating of 2.42) and management of risk (rating of 2.56). All of these are factors of considerable importance.

These internal factors have been barely investigated by previous research documents reviewed during this investigation. Schoeman (1995), Packee (2004), Buthelezi (2004) and Koliasnikoff (1970) focused on the management of closure activities, the integration of closure activities into the operational phase, the method of closure cost estimation and the environmental risk assessment method for the closure phase to a greater extent. They have not investigated internal factors with a view to better or similarly understand the closure issues and goals, or the correct administering of the closure process and how to change activities when a better understanding of the environmental risk has been obtained.

When mine personnel and or managers (rating of 2.96) change frequently during the implementation of a rehabilitation project and or application process for the approval of a rehabilitation plan or closure certificate, it is very important to have a proper record-keeping procedure. The record-keeping procedure must not only contain documentation but must also keep record of all incidents, communications and decisions made during such a rehabilitation project. Monitoring of environmental factors and failures with their findings must be formulated properly and be recorded in a proper record-keeping system with easy accessibility. A proper hand-over between old and new personnel must be done. There normally is not enough time set aside for such a hand-over, because the amount of information is normally very extended and the project must also progress. Document conversion from paper to electronic format will ensure easier access and better searching capabilities that would save much time. This transformation from paper to electronic format, is often not properly done for all documents that will result in an incomplete system where information cannot be accessed easily. Therefore the administration of the record-keeping procedure, which can be combined with a management system like ISO14001, is even more important.

In many instances the operational mine personnel (rating of 3.43) continue with the next phase of decommissioning, rehabilitation and closure. By keeping operational personnel involved, they will facilitate the process with the continuation of activities or incidents that happened and were not recorded as described above. Therefore such personnel need the appropriate training or they need to be assisted or replaced, if above record keeping is implemented, by expertise in the rehabilitation and closure field. Qualified or partly qualified personnel are normally part of the mining personnel because simultaneous rehabilitation needs to be done concurrent to mining activities. Therefore balance between qualified personnel and specialist consultants is

necessary and has to be managed, thus resulting in better management.

During budgeting (rating of 2.93) time for the next financial year a number of activities need to be completed before the budget can be fixed for implementation. One of the phases and probably the most important for the budgeting cycle is the planning phase, which is not valued as high priority or is totally neglected in most cases. This planning phase should include a brief description of environmental impacts, an environmental risk assessment to choose the most appropriate rehabilitation option and a detailed scope of work with all the actions required with their appropriate cost estimates. Mine personnel will always make sure that the budget is spent during the financial year, but inadequate budget planning will either result in implementing activities in the wrong sequence, not performing all the crucial activities, or compromising in the quality of rehabilitation work. The lack of proper plans can also result in a shortage in the closure trust fund, pollution sources not properly addressed and the difficulty of obtaining closure. Therefore the risk to the company increases significantly and needs to be managed (rating of 2.56).

Corporate factors (rating of 2.73) include strategic management of the business unit on site. These factors can include changes to mining plans that can result in earlier closure, approval of operating and rehabilitation budgets which can be reduced and result in improper rehabilitation standards, selling or purchasing of sites which change the rehabilitation trust fund of the company and agreeing with the environmental risks associated to these changes. These risks are often not defined and communicated properly when changes occur.

When mining plans and rehabilitation plans (rating of 2.42) are compiled, all possible fluctuations or options (rating of 2.3) should be considered and the environmental risks (rating of 2.56) to each one need to be defined before the most appropriate rehabilitation option is chosen. Sometimes it does happen that all options are not considered properly or another option realises. The method of managing these fluctuations between actual activities versus original plans (mining, rehabilitation, risks, etc.) will influence the process of obtaining closure for a specific site. When these fluctuations are not properly documented and evaluated, a wrong decision can be made resulting in a difficult situation in order to obtain closure.

Optimal managing and mining of resources (rating of 2.82) need to be done at all times. In these instances it is the tailings material on site that contains gold for processing. Resources like the gold containing tailings do also contain pollutants like salts, cyanide, etc. which leach into soil and water resources. When these tailings materials are not optimally removed through mining activities then rehabilitation options need to be optimised to limit the continual leaching of pollutants. In most of the cases this leaching can only be limited and not totally stopped. The

operational removal costs, rehabilitation costs and environmental degrading costs need to be calculated and compared to make a proper decision to manage the resources optimally.

The selection of detail rehabilitation processes or closure investigations (rating of 3.05) to be compiled, e.g. ground and surface water studies, vegetation programmes, long-term slope stability to prevent erosion, soil quality, detailed engineering designs, social planning, etc. need to originate from a detailed environmental risk assessment with facts and not personal opinions or experiences only. During the risk assessment possible future failures of rehabilitation techniques need to be formulated with a cost comparison between failures and successful rehabilitation that should be motivated with these detailed investigations. The unknowns need to be properly described to serve as a motivation and setting of goals for these detailed investigations. Therefore the end objectives need to be clearly visible to compile detailed rehabilitation actions.

5.6 The strategies of cost estimation for closure before, during and after mine closure

The mine case studies had already been operational when the Environmental Management Programme Report (EMPR) process was promulgated. Therefore some environmental issues and specifically closure issues were not properly resolved and this resulted in these case studies being underprovided in terms of closure funds. Due to these issues the relevant case studies investigated will struggle to obtain proper closure without any complications at the time when residual or latent impacts happen.

All the closure issues discussed above are important to resolve but the most significant closure issue would be that there was not enough information to do a proper probabilistic and quantitative risk assessment to determine all potential impacts. This had a cumulative result in terms of selecting the most appropriate land use and rehabilitation techniques. It is important to take a broader view, and to regard all acts and their regulations as guidelines of equal importance in formulating standards and policies regarding the execution of mining activities that will have an influence on rehabilitation and conservation (Schoeman, 1995:16).

This issue and any other issue that results in problems can be resolved by following the whole mine life cycle from beginning to end. By following this process some completed activities may be sufficient but activities not performed properly must be resolved. When the closure process is under-funded there are normally also not enough funds to re-do the whole mine life cycle closure process. In this situation all the incomplete activities need to be listed and evaluated according to their risk to determine which activities are essential for the closure process to

succeed. This situation can occur regularly during the closure process therefore care must be taken not to spend funds unnecessarily or irresponsibly. There is a fine line in making the correct decision to spend appropriate funds during the closure process to ensure that the closure process succeeds.

5.7 The effect of closure constraints on the closure process flow diagram

One of the main principles to remember is that the individual activities of the mine life cycle as discussed in section 4.6 are interdependent. Therefore, when one of the activities is not performed, or even when one of the activities is not properly attended to and according to proper environmental principles, it will have cumulative effects and can have significant consequences in other areas, for example when a mine site is under-funded in terms of closure costs it may cause difficulty with obtaining closure.

5.8 Conclusion

The problem set out by the research objective (section 1.3) on why these case studies have so much difficulty to obtain closure was discussed in chapter 5. Tailings storage facility footprint case studies do have problems in terms of cost estimation and trust fund expenditure (research question) during the closure process. The problems of obtaining closure and the influence on closure costs were discussed in detail in terms of internal and external factors. It can be concluded that factors like difference in opinions, administration of the closure process, management of risk, political factors, land owners, Interested and Affected Parties (I&APs) and management of the closure life cycle influence the closure costs and closure process the most.

The overall management strategy for closure did not properly incorporate all the necessary variables in terms of probabilistic environmental risk assessment, administration of the Closure Life Cycle (CLC) and proper communication of objectives to state departments, land owners and I&APs. Other influences not conducive to the closure process, were opinions on the environmental risk, which were not based on data scientifically proved and the view of politicians on mining companies that do not address their environmental liability in terms of closure costs.

The overall finding is that a significant problem in terms of changed management when it comes to continuing with consistent management commitments. The main contributor to this problem was the lack of a sufficient, consistent and structured record-keeping system, which indicates changes made during the Closure Life Cycle (CLC) with its relevancy between objectives and cost estimates.

In chapter 6 recommendations will be provided on the findings from chapter 5. Chapter 6 will also give an indication of whether the research questions and goals posed in section 1.3 could be answered and attained.

Chapter 6 Conclusion and Recommendations

6.1 Introduction

In Chapter 5, the data of the Tailings Storage Facility (TSF) case studies in terms of their internal factors, external factors and case specific documents were discussed. The relationship between these factors, closure costs and the Closure Life Cycle (CLC) were discussed. The main issues raised, were the difficulty to manage changes at the case studies and to manage the environmental risk in a systematic CLC. In chapter 6 the research questions and goals (section 1.3) will be discussed in terms of possible conclusions and recommendations.

6.2 Findings and Conclusions

The driver to obtain closure must shift from the State Departments to the mining company. The latter must realise that there are opportunities during the closure process with which money can be made and that can also minimise their long term-liability. The focus of closure must be on the environmental sustainability for future use. This will depend in what way the mining company manages its closure process.

In terms of the research questions to be answered, the following conclusions were made. The first question was about the problems that gold mines might experience at their TSF footprints during the closure process. Managing the closure process and specifically change management is a big problem. Closure estimates need to be updated regularly with new information. There is no common process in terms of contributing and removal of funds from the Closure Trust Fund (CTF). This trust fund process still needs to be defined and implemented.

The second research question was aimed at gaining information on the evaluation of the closure process. The closure process is a very complex process that has to be followed. All the activities in the closure process influence each other. If the activities of the closure process had been done properly and recorded in a proper system every one should have the same expectations defined by the specialists managing the closure process. Therefore the closure process cannot be improved, but it can be simplified to become increasingly user-friendly. The closure process can only be evaluated through using closure factors as defined in this research.

The third question sought information on how the TSF footprint case studies executed the Project Life Cycle (PLC) process to obtain closure. Some of the activities like the

Environmental Management Programme Report (EMPR) compilation, legal approvals, revision of the EMPR, strategic plan to manage personnel, decommissioning and rehabilitation, trust fund establishment, conceptual estimates and update of estimates were done by using the available information. However, according to findings at the sites of the case studies, it appeared that many activities contained in the process flow diagram, had not been put to practice. Therefore the case studies did not adhere to the closure process flow diagram and a proper environmental management system was not implemented. The final rehabilitation, establishing of vegetation, was only done at the end of mine life and not simultaneous to mining activities like earth works.

The intention with the fourth research question was to observe the differences between the activities of the investigated TSF footprint case studies and the requirements of the closure process flow diagram and what way these could assist other closure projects. A conceptual closure plan and a draft rehabilitation plan with broad objectives, policies and strategies with detailed descriptions were not done. Very limited scientific monitoring information was gathered for conducting a proper risk assessment. Some Interested and Affected Parties (I&APs) consultation was done, but mainly with the material and land owners through a one on one basis. This specific process diagram indicated in Figure 5 was not available during the closure process of these case studies, but will certainly solve these problems when sufficient funding is provided.

If the above-mentioned activities had not been done properly the closure process diagram did indicate that these case studies will have higher post-closure monitoring and maintenance costs until the last impact occurs. Therefore the most important activity is the risk assessment to define which route to follow in terms of solving the process diagram activities or following the longer post-closure process. Therefore the uncertainty of residual environmental impacts that are not known or visible at this stage, but surface later do still exist and influence mining companies' way of obtaining closure. These residual impacts need to be identified and preliminary management actions formulated for when they occur. When such a risk assessment is properly done it will also help to quantify costs for activities to overcome environmental risks, and obtain closure.

It was determined that the rehabilitation of mine sites should ideally be planned before any mining commences utilising the data provided by exploration. The data in particular, should include physical, chemical, hydrological and geo-technical properties of the ore, gangue and country rocks, and should be used to develop the Environmental Management Plan (Fourie, 2006:1087). But in most instances and specifically at older mines this process was not

followed.

Planning by middle managers will be more effective when managers develop skills of knowledge regarding jobs in their areas of management, have logical thinking processes, have a mature sense of values, have a foresight and have a sense of timing.

In concluding this discussion on the problems of closing down a South African gold mine it would appear that the biggest contributions towards making the closing down process more efficient, can stem from the administrative and financial sectors (Koliasnikoff, 1970:89). As seen from this research one of the most difficult tasks is to derive appropriate goals and sub-objectives from the objectives set by management. In most instances management sets objectives that are not easily obtainable or practicable and cannot be changed easily because they are legally binding through the EMPR or Closure Plans.

The following concepts were not investigated during this research: Define the different closure processes of operational mines versus dormant mines. Define the closure process necessary during changes in mining activities. Evaluate and define techniques to minimise environmental monitoring costs. Define principles to obtain sustainability after closure. Define the land use development within the closure process. Define a method to determine appropriate rehabilitation techniques, for example review of literature on previous mistakes or trial and error implementation to current best practice. The issue in terms of obtaining partial closure for smaller mining areas within a bigger mining area. Define the closure process of managing the trust fund, for example the withdrawal of funds and spending of funds on rehabilitation work. A guide is necessary on how to spend appropriate funds during the closure process, specifically on environmental investigations and the testing or designing of rehabilitation techniques.

6.3 Recommendations

Planning is the best solution to the problems of closing down a gold mine, but mining companies continue to repeat similar mistakes due to the lack of communicating this planning phase throughout the company.

6.3.1 Any mining operation should conduct a closure audit at least every second year and definitely before mining activities change. During this audit it must be defined at which stage of the Project Life Cycle (PLC) the mining activities are and which earlier stages in the PLC (Figure 5) had not been done or finalised properly or need additional information. This audit will ensure that future Closure Life Cycle (CLC) stages will proceed more successfully.

6.3.2 A record-keeping system must be established to keep track of the CLC development. Changes need to be recorded as well as the reason for change and old records need to be archived. A short summary, especially to elucidate the final closure objectives, rehabilitation methodologies, legal commitments, environmental risks, closure costs and commitments to I&APs must be in place and made available during meetings.

6.3.3 Detailed conceptual and final closure plans need to incorporate the data obtained from section 6.3.1 and section 6.3.2. These plans need to investigate and define the environmental risks, identify point sources of pollution and investigate rehabilitation options and select the best option. This will ensure an easy system that makes it possible to keep track of closure activities with their reasons and assist in the motivation of for what reason the DME can give closure to the mining company for its operations.

6.3.4 A communication forum with company management and environmental specialists needs to be established. During this forum everyone must clearly understand the environmental risks at all operations and in what way management decisions will influence the environmental risk. The progress of the CLC phases also need to be explained, especially the post-closure period, which ends when the final impact occurs.

It will be in the best interest of all, mining companies included, to obtain closure of mining sites when the time for doing so arrives. The closure process can be costly and is a very lengthy and tedious process. Closure is possible, but only if all stakeholders cooperate as efficiently as possible to make the end result of obtaining closure possible. By implementing the abovementioned recommendations most problems and difficulties of the closure process and especially the problems experienced at the investigated case studies, will be reduced.

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Appendix 1: Questionnaire

1) Was a record-keeping system in place throughout the mine life cycle? (1 – No, 3 – Sort of but not easily accessible; 5 – Yes)

Purpose of question: To determine whether information was easily accessible.

2) Were the environmental conditions and risks determined in detail at all the Tailings Storage Facilities (TSFs) before mining activities started? (1 – No not at all; 2 – Limited for some sites, 3 – Unknown, 4 – Detail for most sites, 5 – Yes in detail for all the sites)

Purpose of question: To determine whether environmental performance was monitored.

3) How regularly was the mining plan changed? (1 – very regular, 5 –not regular)

Purpose of question: If 1 then we know there was difficulty with the mining process. With these changes there can be many changes in the environmental impacts.

4) Did high rainfall days influence the mining activities on the TSF footprints and how regularly? (1 – Yes very regularly and stopped mining activities totally, 5 – No not regularly)

Purpose of question: There is a possibility that environmental risks were not investigated for the time when mining activities were interrupted.

5) Was the necessary documentation like the EMP and or rehabilitation plans adapted after the change of mine plan? (1 – No, 5 –Yes)

Purpose of question: To determine how regularly the EMP was updated.

6) Did management change often? (1 – Yes, 5 – No)

Purpose of question: To determine continuity of the decision-making process.

7) Were the mining operations and the rehabilitation activities separated processes or were they performed simultaneously, therefore integrated with each other? (1 – No, 5 – Yes simultaneously)

Purpose of question: To determine the importance of environmental issues, the change of impacts and the management of environmental impacts.

8) Was environmental monitoring done consistently at regular intervals from pre-mining until after closure? (1 – No, 5 – Yes)

Purpose of question: To determine whether a tract record of environmental performance of improvement or detrimental effect can be followed for decision makers.

9) Were there enough trained employees to assist with mining activities? (1 – No, 5 – Yes)

Purpose of question: To determine the skills available to solve problems when they occur.

10) Were specialist consultants or contractors used for the compilation of specialist studies and or rehabilitation plans? (1 – No, 5 – Yes)

Purpose of question: To determine the skills used to determine rehabilitation activities.

11) Was the grade of gold obtained at the plant the same as the forecast grade as defined during exploration? (1 – No, 5 – Yes)

Purpose of question: To determine how accurately and efficiently mining and or environmental investigations were done.

12) Were detailed investigations conducted and recorded during the exploration phase? (1 – No, 5 – Yes)

Purpose of question: To determine whether these investigations were completed and whether the results were recorded for future use, e.g. in during rehabilitation planning activities.

13) Was cost estimation for closure based on detail engineering designs or on experience from completed work? (1 – On Experience, 5 – On detail eng. designs)

Purpose of question: To determine the accuracy level and confidence level of rehabilitation activities.

14) Was a full-time environmental co-ordinator involved during mining activities (whole mine life cycle)? (1 – No – very seldom, 3 – from time to time on an ad-hoc basis, 5 – Yes)

Purpose of question: To assess the quality of the managing of environmental risks.

15) How regularly did the State Department representatives meet with mine management? (1 – Very seldom, 2 – Six monthly, 3 – Yearly, 4 – Quarterly, 5 – Monthly)

Purpose of question: To determine the detail involvement and guidance from the State Departments.

16) Did changes in the environmental legislation enhance the closure process? (1 – No, 2 – Very little, 3 – Unknown, 4 – Significantly, 5 – Yes totally)

Purpose of question: To determine the result of changing environmental legislation.

17) How regularly did the land owner and I&APs representatives meet with mine management? (1 – Very seldom only when necessary, 2 – Every two Years, 3 – Yearly, 4 – Quarterly, 5 – Monthly)

Purpose of question: To determine the extent of involvement from the I&APs.

18) From experience and observations did other mining companies with similar sites adjacent to these tailings footprints implement similar rehabilitation technologies? (1 – No – they did nothing, 2 – No – very seldom, 3 – Not sure, 4 – from time to time on an ad-hoc basis, 5 – Yes very similar technologies)

Purpose of question: To determine activities of other companies on an informal basis. (For future reference, to be confirmed through additional data and information collection, this will not form part of this investigation. This might be a motivation for companies and or the state departments to compare mining companies through publishing statistics that are similar to the same type of mining site. This can also act as a motivation for mining companies to perform better in terms of their closure commitments.)

19) Was a record-keeping system on paper and electronic format in place throughout the mine life cycle? (1 – No; 3 – Sort of but not easily accessible; 5 – Yes)

Purpose of question: To determine whether information was easily accessible.

20) Was environmental monitoring done on a continual basis throughout the mine life cycle at all the TSF footprints? (1 – No not at all; 2 – Limited for some sites, 3 – Unknown, 4 – Detail for most sites, 5 – Yes in detail for all the sites)

Purpose of question: To determine whether environmental performance was monitored.

21) Were the mining activities stopped and started regularly? (1 – very regular, 5 – not regular)

Purpose of question: There is a possibility that environmental risks were not investigated for the time when mining activities did not continue or continue again.

22) Did high rainfall days influence the rehabilitation activities on the TSF footprints and how regularly? (1 – Yes very regularly and stopped rehabilitation activities totally, 5 – No not regularly)

Purpose of question: There is a possibility that environmental risks were not investigated for the time when rehabilitation activities were interrupted.

23) Did the management documents (EMP and Rehabilitation plan) contain enough rehabilitation detail for easy implementation? (1 – No, 5 – Yes)

Purpose of question: To determine how complete the management plans were and how much fluctuation occurred between activities and plans.

24) Did employees change often? (1 – Yes, 5 – No)

Purpose of question: To determine continuity of the decision-making process and competence of the employees.

25) When mining operations stopped (or abandoned the tailings footprint) before all the tailings material had been removed from the area, was a risk assessment done to compare removal costs (inclusion of environmental cost) with rehabilitation costs (inclusion of environmental cost)? (1 – No, 2 – Very limited detail, 3 – Unknown, 4 – Partly, 5 – Yes with all mentioned detail)

Purpose of question: To determine the importance of environmental issues, the change of impacts and the management of environmental impacts. Also to determine whether adequate detail was available to make a proper decision.

26) Were there enough trained employees to assist with rehabilitation activities? (1 – No, 5 – Yes)

Purpose of question: To determine the skills available for managing environmental activities.

27) Were specialist consultants or contractors used to assist with the implementation of rehabilitation activities and the auditing thereof? (1 – No, 5 – Yes)

Purpose of question: To determine the skills used to monitor rehabilitation activities.

28) Did exploration continue during the mining activities? (1 – No, 5 – Yes)

Purpose of question: To determine whether investigations were updated to assist with environmental decision making.

29) Was a proper scope of work compiled during budgeting for the following year's rehabilitation activities of closure and was it based on detailed designs (engineering/ closure plans/ EMPR) or on experience from completed work? (1 – On Experience, 5 – On detail eng. designs)

Purpose of question: To determine the accuracy level and confidence level of rehabilitation activities.

30) Were a full time environmental co-ordinator and/ or engineer and/ or consultant and/ or specialist involved during rehabilitation activities? (1 – No, 3 – very seldom, 4 – From time to time on an ad-hoc basis, 5 – Yes regularly)

Purpose of question: To indicate the detail managing of environmental risks.

31) How regularly did the land owner and I&APs representatives visit the rehabilitation sites? (1 – Very seldom, 2 – Yearly, 3 – Six monthly, 4 – Quarterly, 5 – Monthly)

Purpose of question: To determine the involvement of the I&APs.

32) Are the assumptions true that the mining industry in general results in major and long-term environmental polluters and that operations lack preventative measures and proper rehabilitation activities? (1 – Yes, 2 – from time to time on a ad-hoc basis, 3 – Not sure, 4 – No – very seldom, 5 – No)

Purpose of question: To test whether this statement is valid.

33) Was a record-keeping system for all related information like normal communications, decisions made, commitments made, failures and environmental incidents in place throughout the mine life cycle? (1 – No; 3 – Sort of but not easily accessible; 5 – Yes)

Purpose of question: To determine whether all information is easily accessible.

34) Was environmental monitoring at the TSF footprints derived from the goals set in the EMPR or rehabilitation plans? (1 – No not at all; 2 – Limited for some sites and resulted as part of general mining activities, 3 – Unknown, 4 – Partly obtained from EMPR and rehabilitation plans, 5 – Yes in detail for all the sites)

Purpose of question: To determine whether environmental performance is monitored properly.

35) Were environmental risks evaluated each time when the mining plan changed (or when it stopped and started)? (1 – No, 3 – partly, 5 – Yes in detail)

Purpose of question: To determine whether the mining plan incorporated environmental risks.

36) Did the management documents (EMP and Rehabilitation plan) assist with each year's budgeting cycle? (1 – No, 5 –Yes)

Purpose of question: To determine how complete the management plans were and how regularly the management plans were used to assist decision making.

37) Did the rehabilitation activities follow immediately after the mining activities had ceased? (1 – No, 5 – Yes)

Purpose of question: To determine the importance of environmental issues, the change of impacts and the management of environmental impacts.

38) Were the same employees used both for mining and for rehabilitation activities? (1 – Yes, 5 – No)

Purpose of question: To determine the skills available for managing environmental activities.

39) Was much maintenance necessary after rehabilitation had been completed? (1 – Yes, 5 – No)

Purpose of question: To determine the success of rehabilitation.

40) Were detailed environmental investigations conducted during the exploration phase? (1 – No, 5 – Yes)

Purpose of question: To determine whether such investigations had been conducted in detail to be used during rehabilitation planning activities.

41) Did budget cuts take place on the basis of doing the same work with less money or were rehabilitation activities postponed to later years? (1 – Same amount of work needed to be completed, 5 – Work was delayed)

Purpose of question: To determine whether the amount of money to proceed with rehabilitation activities was sufficient.

42) How regularly did the state department representatives visit the rehabilitation sites? (1 – Very seldom, 2 – Six monthly, 3 – Quarterly, 4 – Yearly, 5 – Monthly)

Purpose of question: To gain more information on the extent of involvement and guidance from the state departments.

43) Are the general assumptions true that this company is a major and long-term environmental polluter that lacks the necessary preventative measures and proper rehabilitation activities? (1 – Yes, 2 – from time to time on an ad-hoc basis, 3 – Not sure, 4 – No – very seldom, 5 – No)

Purpose of question: To test whether this statement is valid in this specific situation.

44) Were all documents easily available throughout the mine life cycle? (1 – No, 5 –Yes)

Purpose of question: To determine how efficient the record keeping was.

45) Were all failures and or incidents recorded in a formal system? (1 – No, 5 – Yes)

Purpose of question: To gain information on the record-keeping system and the use of previous information to prevent mistakes or problems.

46) Did the decommissioning and demolition of infrastructure form part of the mining activities when it ceased or were they part of the rehabilitation activities? (1 – Yes part of mining activities, 5 – No part of rehabilitation activities)

Purpose of question: To determine whether sufficient infrastructure was in place for different possible rehabilitation options.

47) Was the result of budget cuts a reduction in the quality of rehabilitation activities or was it a result of implementing smarter and more appropriate rehabilitation techniques? (1 – Quality of work was reduced, 5 – Smarter rehabilitation techniques)

Purpose of question: To determine the effect of budget cuts on rehabilitation activities and the

risk to obtain closure.

48) Were all the relevant state departments involved each time during meetings and or site visits? (1 – No – they never attended, 2 – Very seldom, 3 – Not sure, 4 – from time to time on an ad-hoc basis, 5 – Yes - Always)

Purpose of question: To determine the extent of involvement and guidance from the state departments.

49) Was a summary of the commitments made by the mining company to material owners, land owners and I&APs for each TSF footprint easily accessible? (1 – Available in the library, 2 – Contained in detail contract, 3 – Not sure, 4 – Paper document, 5 – Digital document)

Purpose of question: To determine the extent of involvement of the mining company with the I&APs.

50) Was an environmental risk assessment done during or before budget cuts to define the risk in reducing the quality of rehabilitation activities or the use of smarter and more appropriate rehabilitation alternative techniques? (1 – No risk assessment was ever done, 5 – Yes a risk assessment was done each year for budget cuts)

Purpose of question: To determine the effect of budget cuts on rehabilitation activities (also fluctuations between actual activities and planned activities) and the risk to obtain closure.

51) Did state department representatives change often? (1 – Yes – Regularly less than six-monthly basis, 2 – Often on a yearly basis, 3 – Unknown, 4 – Seldom on a two-yearly basis,5 – Never)

Purpose of question: To determine continuity of the decision-making process.

52) Was a summary of the expectations (final rehabilitation goals) from material owners, land owners and I&APs for each TSF footprint easily accessible? (1 – Available in the library, 2 – Contained in detail legal contract, 3 – Not sure, 4 – Paper document, 5 – Digital document)

Purpose of question: To determine the extent of involvement of the mining company with the I&APs.

53) Were the state department representatives briefed by their manager before meetings or site visits to know current state department commitments made during previous meetings or documents and did they know the critical environmental risks at these footprints? (1 – Never, 2 – Seldom, 3 – Unknown, 4 – Often, 5 – Yes – Updated fully)

Purpose of question: To determine continuity of the decision-making process and state department knowledge.

54) Were detailed engineering designs followed on a step by step basis during rehabilitation activities? (1 – No only experience was used, 5 – Yes detailed engineering designs were followed exactly)

Purpose of question: To determine the accuracy of rehabilitation activities to obtain the forecast or planned end product. Also to determine whether there were fluctuations between actual activities and planned activities.

55) Did the state department representatives' knowledge on these footprints improved over time in terms of current state department commitments made during previous meetings or in documents and their understanding of critical environmental risks? (1 – No, 3 – Unknown, 5 – Yes)

Purpose of question: To determine continuity of the decision-making process and knowledge status of representatives from state departments.

56) Were mine management and or personnel flexible in their opinions when changes occurred with regard to new environmental technologies and changes in legislation and were they reluctant to change their ideas when influencing the strategic direction to follow with addressing pollution, environmental monitoring, rehabilitation activities, closure planning and closure applications? (1 – No, 2 – Sometimes, 3 – Unknown, 4 – Frequently, 5 – Yes always)

Purpose of question: To determine continuity and quality of the decision-making process.

Appendix 2: Summary of the calculations after the interviews

Questions and Categories	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5
1	1	3	2	3	1
2 to 55					
56	2	2	3	2	2
Sum of all Questions	176	167	133	181	113
Average for all Questions	3.14	2.98	2.38	3.23	2.02
External Factors Average	**2.87**	**3.00**	**1.95**	**2.77**	**1.92**
Political	2.50	2.50	1.00	3.50	1.50
Affirmative Action	3.20	2.60	1.60	3.40	2.40
Legislation	2.50	2.75	2.75	3.00	1.75
Legislator	3.20	2.80	2.00	3.60	2.40
Mine Life Cycle	3.00	2.67	2.33	2.22	1.89
Weather	3.00	5.00	2.00	1.00	2.00
Land Owners & I&APs	2.70	2.70	2.00	2.70	1.50
Internal Factors Average	**2.96**	**2.91**	**2.28**	**3.07**	**1.79**
Personnel	3.67	4.00	2.83	4.67	2.00
Management	2.80	3.80	3.20	2.80	2.20
Budget	3.71	2.86	2.64	3.36	2.07
Risk Management	2.85	2.85	2.30	2.85	1.95
Corporate	3.00	3.11	2.78	3.00	1.78
Resources	3.37	2.89	2.47	3.16	2.21
Investigations	3.85	2.77	2.54	3.92	2.15
Objectives	3.07	3.20	2.53	3.20	1.93
Monitoring	4.10	3.80	2.30	3.90	2.10
Administrative	2.67	3.11	1.56	3.44	1.33
Opinions	2.50	2.50	2.25	2.50	1.75
Rehabilitation Techniques	3.27	3.18	2.36	2.64	2.27

Appendix 3: Figures of Case Study Areas

Figure 6: Case study site A

Figure 7: Case study site B

Figure 8: Case study site C

Figure 9: Case study site D

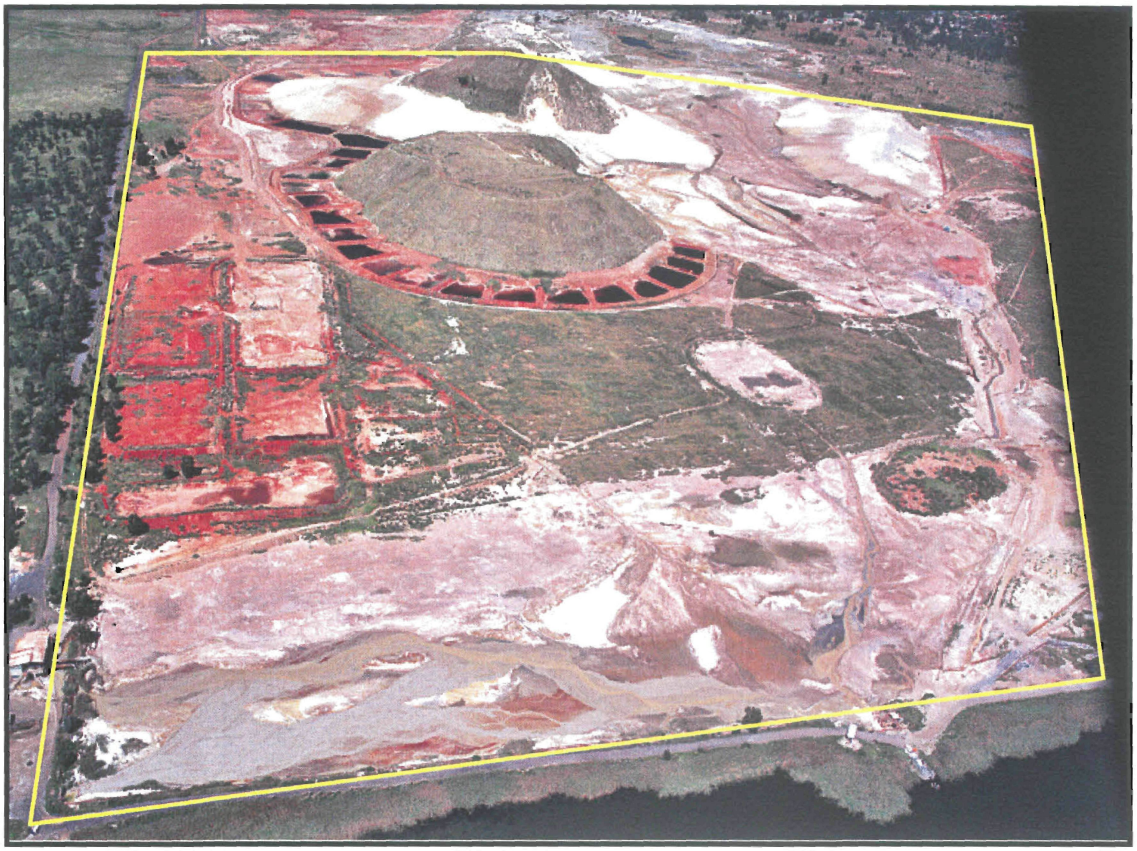

Figure 10: Case study site E