



Australian Government

Department of Industry  
Tourism and Resources

# MINE CLOSURE AND COMPLETION

LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY



SOCIAL  
ECONOMIC  
ENVIRONMENTAL



LEADING PRACTICE SUSTAINABLE  
DEVELOPMENT PROGRAM FOR  
THE MINING INDUSTRY

## MINE CLOSURE AND COMPLETION



OCTOBER 2006

## **Disclaimer**

Leading Practice Sustainable Development Program for the Mining Industry

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## FOREWORD

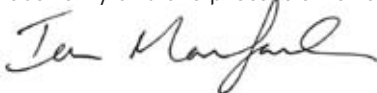
The Australian mining industry is well aligned to the global pursuit of sustainable development. A commitment to leading practice sustainable development is critical for a mining company to gain and maintain its 'social licence to operate' in the community.

The handbooks in the Leading Practice Sustainable Development in Mining series integrate environmental, economic and social aspects through all phases of mineral production from exploration through construction, operation and mine site closure. The concept of leading practice is simply the best way of doing things at a given site. As new challenges emerge and new solutions are developed, or better solutions are devised for existing issues, it is important that leading practice be flexible and innovative in developing solutions that match site-specific requirements. Although there are underpinning principles, leading practice is as much about approach and attitude as it is about a fixed set of practices or a particular technology. Leading practice also involves the concept of 'adaptive management', a process of constant review and 'learning by doing' through applying the best of scientific principles.

The International Council on Mining and Metals (ICMM) definition of sustainable development for the mining and metals sector means that investments should be technically appropriate, environmentally sound, financially profitable and socially responsible. *Enduring Value - the Australian Minerals Industry Framework for Sustainable Development* provides guidance for operational level implementation of the ICMM Principles and elements by the Australian mining industry.

A range of organisations have been represented on the steering committee and working groups, indicative of the diversity of interest in mining industry leading practice. These organisations include the Department of Industry, Tourism and Resources; the Department of the Environment and Heritage; the Department of Industry and Resources (Western Australia); the Department of Natural Resources and Mines (Queensland); the Department of Primary Industries (Victoria); the Minerals Council of Australia; the Australian Centre for Minerals Extension and Research, the university sector and representatives from mining companies, the technical research sector, mining, environmental and social consultants; and non-government organisations. These groups worked together to collect and present information on a variety of topics that illustrate and explain leading practice sustainable development in Australia's mining industry.

The resulting publications are designed to assist all sectors of the mining industry to reduce the negative impacts of minerals production on the community and the environment by following the principles of leading practice sustainable development. They are an investment in the sustainability of a very important sector of our economy and the protection of our natural heritage.



**The Hon Ian Macfarlane MP**  
Minister for Industry, Tourism and Resources





# 1.0 INTRODUCTION

This handbook addresses mine closure and completion, one of the themes in the Leading Practice Sustainable Development Program. The program aims to identify key issues affecting sustainable development in the mining industry and provide information and case studies that illustrate a more sustainable basis for the industry. There are a number of other themed handbooks in the series, which aim to complement this handbook. The leading practice handbooks are relevant to all stages of a mine's life exploration, feasibility, design, construction, operation and closure and to all facets of an operation.

The future of the mining industry is dependent on the legacy it leaves. Its reputation is affected when mines are abandoned or long-term detrimental environmental issues emerge because they have not been appropriately addressed. The industry today recognises that to gain access to future resources it needs to demonstrate that it can effectively close mines with the support of the communities in which it operates. The industry needs to embrace the concept of completion of mining as a defined end point rather than just closure, when the operational stage of a mine ceases and decommissioning is complete.

The primary audience for this handbook is managers at the operational level, the pivotal level for implementing leading practice arrangements at mining operations. In addition, people with an interest in leading practice in the mining industry including mining company directors, managers, community relations practitioners and environmental officers, mining consultants, governments and regulators, non-government organisations, neighbouring and mine communities and students will find this handbook relevant. It has been written to encourage these people to play a critical role in continuously improving the mining industry's sustainable development performance.

Within this handbook, the terms, 'mine closure' and 'mine completion' are used. Mine closure is a process. It refers to the period of time when the operational stage of a mine is ending or has ended, and the final decommissioning and mine rehabilitation is being undertaken. Closure may be only temporary in some cases, or may lead into a program of care and maintenance. In this sense, the term mine closure encompasses a wide range of drivers, processes and outcomes.

Mine completion is the goal of mine closure. A completed mine has reached a state where mining lease ownership can be relinquished and responsibility accepted by the next land user. To achieve this in an environment of increasing regulatory and stakeholder expectations requires that superior outcomes are developed and implemented in consultation with relevant stakeholders, including local communities.

Mine completion ultimately determines what is left behind as a benefit or legacy for future generations. If mine closure and completion are not undertaken in a planned and effective manner, a site may continue to be hazardous and a source of pollution for many years to come. The overall objective of mine completion is to prevent or minimise adverse long-term environmental, physical, social and economic impacts, and to create a stable landform suitable for some agreed subsequent land use. This handbook describes the business case for planned, structured and systematic mine closure and completion of mines in the context of sustainable development, and the leading practice approaches to achieve successful mine closure and completion. A number of case studies are used to illustrate various aspects of closure planning.



## 2.0 SUSTAINABLE DEVELOPMENT

In a perfect world, mines only close when their mineral resources are exhausted and a mine closure plan is in place and progressively implemented. There is time available for planning, monitoring and trials, and funds are externally held to cover the costs of implementing the closure plan. Pre-determined outcomes can be achieved or progressed satisfactorily and there should be ample opportunity to overcome any major issue that may create problems after closure. Stakeholders are prepared for the intended closure date, employees can plan to find alternative employment, and the community has the opportunity to work with the mine to ensure sustainable benefits from the mining activities.

However, in the real world, mines extract reserves not resources, and the grade and tonnage of reserves vary from day-to-day depending on the commodity price, ore quality or grade, further exploration results, geotechnical complications and other factors which can result in mine closure before the estimated reserve has been fully extracted. This situation can create significant problems for the mining company, the community and the regulator.

There are many reasons why mines may close prematurely. Research shows that almost 70 per cent of the mines that have closed over the past 25 years in Australia have had unexpected and unplanned closures (Laurence, 2002). That is, they have closed for reasons other than exhaustion or depletion of reserves. These include:

- economic, such as low commodity prices or high costs that may lead a company into voluntary administration or receivership
- geological, such as an unanticipated decrease in grade or size of the ore body
- technical, such as adverse geotechnical conditions or mechanical/equipment failure
- regulatory, due to safety or environmental breaches
- policy changes, which occur from time-to-time, particularly when governments change
- social or community pressures, particularly from non-government organisations
- closure of downstream industry or markets
- flooding or inrush.

Poorly closed and derelict (orphaned and abandoned) mines provide a difficult legacy issue for governments, communities and minerals companies and, ultimately, tarnish the mining industry as a whole. Increasingly, as access to resources becomes tied to industry and corporate reputation, effective closure processes and satisfactory mine completion becomes critical to a company's ability to develop new projects. Poor planning and inadequate financing commonly increase the costs of closure and decrease overall profitability, hampering a company's ability to develop new projects.

Taking a more integrated approach to mine closure planning, and doing it earlier, can achieve effective mine closure and completion, and ameliorate the negative effects of unexpected or unplanned closures.

Recently, a range of sustainable development policy frameworks have been developed by industry and other organisations that are now acting as drivers for improved practice. One such approach is that by the International Council on Mining and Metals (ICMM) which adopted a set of 10 Sustainable Development Principles in 2003 to harness the industry's commitment to sustainable development within a strategic framework (ICMM, 2003).

To give practical and operational effect to the ICMM commitments, the Minerals Council of Australia (MCA) developed *Enduring Value - The Australian Minerals Industry Framework for Sustainable Development* (MCA, 2004). Enduring Value is designed to assist minerals sector managers to implement the sector's commitment in a practical and operational manner that is targeted at the site level (MCA, 2005).

In adopting Enduring Value, the Australian minerals sector is recognising that its future is linked to the pursuit of sustainable development, which means operating in a manner that is attuned to community expectations and which acknowledges that business has a shared responsibility with government, and with broader society, to help to facilitate the development of strong and sustainable communities (MCA, 2005).

The vision of a mine closure and completion plan should be to ensure that a process is established to guide all decisions and actions during a mine's life such that:

- future public health and safety are not compromised
- environmental resources are not subject to physical and chemical deterioration
- the post-mining use of the site is beneficial and sustainable in the long term
- any adverse socio-economic impacts are minimised
- the opportunity is taken to maximise socio-economic benefits (Mining, Minerals and Sustainable Development (MMSD) Project 2002).

The following sections in this chapter further consider the environmental, social and economic issues which underpin the business case for leading practice mine closure and completion planning, outline the strategy and objectives of the closure process, and address the elements of managing closure risk.

**Table 1: Enduring Value - Overview of key principles and elements related to mine closure**

<p><b>Principles and elements</b></p> <p><b>Principle 2: Integrate sustainable development considerations within the corporate decision-making process</b></p> <ul style="list-style-type: none"><li>• Plan, design, operate and close operations in a manner that enhances sustainable development. (element 2.2)</li></ul>
--

**Principle 4: Implement risk management strategies based on valid data and sound science**

- Consult with interested and affected parties in the identification, assessment and management of all significant social, health, safety, environmental and economic impacts associated with our activities. (element 4.1)
- Inform potentially affected parties of significant risks from mining, minerals and metals operations and of the measures that will be taken to manage the potential risks effectively. (element 4.3)

**Principle 6: Seek continual improvement of environmental performance**

- Assess the positive, negative and indirect and the cumulative impacts of new projects—from exploration through closure. (element 6.1)
- Rehabilitate land disturbed or occupied by operations in accordance with appropriate post-mining land uses. (element 6.3)
- Design and plan all operations so that adequate resources are available to meet the closure requirements of the operations. (element 6.5)

**Principle 9: Contribute to the social, economic and institutional development of the communities in which we operate**

- Contribute to community development from project development through closure in collaboration with host communities and their representatives (element 9.3)

**Principle 10: Implement effective and transparent engagement, communications and independently verified reporting arrangements with stakeholders**

([www.minerals.org.au/enduringvalue](http://www.minerals.org.au/enduringvalue)).

## 2.1 Sustainable development issues for closure

### 2.1.1 Environmental issues

Central to a closure plan is the development of a progressive rehabilitation plan which ensures:

- the post-mined landscape is safe and is stable from physical, geochemical and ecological perspectives
- the quality of the surrounding water resources is protected
- the agreed sustainable post-mining land use is established and clearly defined to the satisfaction of the community and government
- success criteria are agreed with relevant stakeholders, monitored and reported to stakeholders.

The development of a mining operation, including associated processing facilities and infrastructure, usually involves the permanent alteration of existing landforms, disturbance to vegetation and flora, disruption of fauna habitats, hydrological impacts and potentially some level of contamination (see Table 1).

**Table 2: Alterations to existing landforms**

- **Topography and landform:** Temporary changes to the existing topography from mining operations include access and haul roads, laydown and hardstand area,; topsoil stockpiles, process plant site, and support infrastructure. Permanent changes include open pit void; waste rock dumps; and tailings storage facilities.
- **Flora and vegetation:** Direct impacts on flora and vegetation communities will mainly occur through clearing for the mine, waste rock dumps, processing plant, tailings storage facility and associated infrastructure.
- **Fauna:** The impact of mining on fauna can generally be described as either primary or secondary. The primary impact of mining on fauna is the direct destruction of habitats through land clearing and earthmoving activities. Secondary impacts relate to activities with varying degrees of disturbance beyond the immediate point where mining is taking place, such as access and haul roads, powerlines, pipeline corridors and other infrastructure, feral animals and general workforce activities.
- **Surface water hydrology and groundwater:** The development of the open pits, stockpiles, waste rock dumps, tailings storage facilities, processing plant and infrastructure often interrupt some of the natural drainage paths. Interference with drainage patterns may result in deprivation of water to drainage systems downstream of the mining developments or localised 'shadowing' effects on some vegetation which may be reliant on intermittent flows.
- **Soil and water contamination:** Chemical reactions in waste rock and tailings have the potential to be detrimental to plant growth and to result in contamination of both surface and groundwater. In addition, mining and processing operations transport, store and use a range of hazardous materials including fuels, process reagents, lubricants, detergents, explosives, solvents and paints. If these materials are not properly managed, they may have the potential to cause atmospheric, soil or water contamination and could potentially pose ongoing risks to human health and the environment.

Environmental management of these issues during operations can assist in minimising the impacts. However, there will inevitably be residual impacts at the completion of the mining and processing operations that will need to be managed with regard to the following priorities: public safety hazards and risk, potential sources of ongoing pollution, future land use and resource demands, ecological compatibility, community expectations, aesthetics and cost.

Many of the aspects outlined above and resultant impacts depend on the nature of the project and site-specific environmental factors. It is therefore important to define these aspects and impacts for each project as part of the mine closure planning process.



There may be opportunities to reduce the environmental impact of mining and mineral processing through the design and operation of processing plants to produce less toxic wastes, or to re-use and recycle these wastes through cleaner production and industrial ecology initiatives (see the Stewardship handbook in this series).

Additionally, it may be possible to partially offset the environmental impacts of mining by the rehabilitation of non-mined land. These point to the importance of considering closure and completion issues from the very earliest stages of mine planning.

Further information on potential impacts (and measures to reduce them) is tabulated in Appendix A.

### **2.1.2 Socio-economic issues**

Through Enduring Value, the Australian minerals industry has made a commitment to the social and economic development of the communities in which companies operate. This entails a commitment to minimise the adverse impacts of mining on neighbouring communities, and also raises the issue of how to maintain or improve the wellbeing and social sustainability of affected communities. Social sustainability refers to the formal and informal processes, systems, structures and relationships within a community that actively support the capacity of current and future generations to create healthy and liveable communities. Socially sustainable communities are equitable, diverse, connected and democratic, and provide a good quality of life (Western Australian Council of Social Services, 2002).

Community development programs provide an important mechanism through which a mining company can contribute to social sustainability. Community development is centrally concerned with increasing the strength and effectiveness of communities in determining and managing their own futures (ESMAP/World Bank/ICMM, 2005). It involves planning and implementing initiatives, often in partnership with other stakeholders, to provide long-term positive outcomes for affected communities. Community development should be driven by the needs of the community, not the company and should seek to contribute to the long-term strengthening of community viability.

In many remote and regional areas, mining operations provide the only significant mainstream economic activity and have a critical role and contribution to make to regional economic development. Mining operations provide clear training and employment opportunities across the professions, skills and services. In some cases, mining companies are extending their commitment to local economic development and capacity building by requiring that contractors also target their training and employment opportunities to the local community, and by giving preference to a local supply chain. Mining companies are also seeking to provide appropriate skills-transfer and employment opportunities through the development of local business enterprises.

The establishment of a mining or minerals operation almost always brings significant infrastructure to the mine site, to the local community and to the broader region. Planning for mine closure can assist in mitigating the consequent reduction in access to useful infrastructure. With advanced and careful planning, it may be possible to develop capacity to maintain certain infrastructure facilities and services for

future community or local government ownership or as part of arising business development opportunities.

A company's community development program will be informed by the company's community engagement strategy which should be a dynamic and ongoing process throughout the life cycle of the mining operation. Planning for mine closure should be raised with the community as early as possible prior to the planning and design phase. The project design should consider how to minimise the adverse impacts of mine closure and to optimise the opportunities for community development that arise from the active mining and mine closure phases. An early and effective community engagement strategy should be established and the community engaged throughout the life of the operation.

The Leading Practice handbook entitled Community Engagement and Development provides further information and case studies on best practice for effective community engagement and community development programs. In particular, planning for mine closure should ensure that the future public health and safety of the community is not compromised; the community's resilience to the adverse impacts of mine closure is strengthened; and the community can maximise opportunities for consequential land use and retain mining infrastructure of value to the community.

### **2.1.3 Business case**

There is a business case for approaching mine closure within a sustainable development framework in a planned, structured and systemic manner that is progressively implemented over the whole project cycle. The benefits include:

#### **Improved mine management:**

- opportunities to optimise mine planning and operations during active mine life for efficient resource extraction and post-mining land use (for example reduction of double-handling for waste materials and topsoil, and reduced areas of land disturbance)
- identification of areas of high risk as priorities for ongoing research or remediation
- progressive implementation of a mine closure plan with opportunities for ongoing effectiveness testing, assessment and feedback
- lower risk of regulatory non-compliance.

#### **Improved stakeholder engagement in planning and decision-making:**

- understanding the likely impacts on affected communities in terms of environmental, social and economic impacts of mine closure
- informed development of strategies and programs to address closure impacts, ideally as part of a community development approach from early in the mine's life
- increased support from employees, government, landholders, local community and other stakeholders for closure decisions
- improved community receptiveness to future mining proposals
- enhanced public image and reputation.

### Reduction of risks and liabilities:

- assured financial and material provision for mine closure through early estimation of mine closure costs
- continual reduction of liabilities by optimising operational works during active mine life in alignment with closure plan
- reduction of exposure to contingent liabilities related to public safety and environmental hazards and risks
- reduction of ongoing responsibilities for the site and facilitation of timely relinquishment of tenements and bond recovery.

## 2.2 Closure objectives, strategy and context

### 2.2.1 Objectives

The objectives of a mine closure and completion plan to achieve the vision outlined in Section 1.0 are (ANZMEC/MCA 2000):

- enable all stakeholders to have their interests considered during the mine closure process
- ensure the process of closure occurs in an orderly, cost-effective and timely manner
- ensure the cost of closure is adequately represented in company accounts and that the community is not left with a liability
- ensure there is clear accountability and adequate resources for the implementation of the closure plan
- establish a set of indicators which will demonstrate the successful completion of the closure process
- reach a point where the company has met agreed completion criteria to the satisfaction of the responsible authority.

### 2.2.2 Strategy and context

The closure planning process to achieve sustainable development outcomes in closure will change long-term business strategies as the risks and opportunities associated with closure become better understood. To be effective, sustainable closure planning should be viewed in context and be part of a larger sustainable development strategy.

**Figure 1: Closure strategy and context**



## **Policy**

A site closure/completion policy sets the high-level aspirations and directions that the company requires for mine closure. Typically the policy will make commitments about the closure process, stakeholder engagement, environmental minimisation of risk, meeting regulatory requirements, social and community aspirations, and continuous improvement.

The policy should recognise that it is possible to anticipate some aspects of the legacy of a mine at its conception, include closure as part of mine planning, identify risks and opportunities for reliable financial planning and costing, and determine final land-use objectives and principles in consultation with the community. All these factors show the need for progressive rehabilitation and to consider the needs of the community affected by closure. Usually, this policy is supported by organisational standards, guidelines and methodologies that outline how the implementation of the policy will be achieved.

## **Performance objectives, criteria and indicators**

Closure planning requires the establishment of a performance framework for mine closure that enables success in closure to be measured and facilitates a consistent approach to closure. The framework consists of standards and principles, objectives and criteria which form the basis for assessing mine closure plans and proposed closure options, and identifying key performance indicators.

The framework typically covers:

- rehabilitation principles and objectives, including final land use
- decommissioning requirements
- community objectives and criteria
- consent criteria
- standards and issues related to whole-of-life considerations
- financial costing and provisioning
- legal requirements
- environmental and social management requirements
- safety considerations.

## **Information, data collection, analysis and records management**

Having the right information to make the best technical and social decisions in closure planning requires the collection, assessment and management of environmental, social and economic data. It is necessary to continually review of site characterisation, baseline study information and of the risks and opportunities of closure (Section 2.3). It is important at this step to understand the range of stakeholder requirements including community expectations for final land use, cultural and heritage values, government regulation and other legal requirements. Early identification of data gaps helps guide any research and development programs needed to demonstrate the effectiveness of unproven rehabilitation strategies. A data recording and management system will help the closure planning team in understanding the status of closure issues.

## Case study: Bottle Creek Mine, Western Australia

This case study of an unplanned closure makes three important points:

- it can take considerable persistence by a company to achieve relinquishment, particularly if early rehabilitation is inadequate for the task
- the selection of a robust and verifiable process to monitor and demonstrate completion criteria is crucial for closure
- early establishment of verifiable completion criteria is critical to receiving acceptance and approval for relinquishment by the regulator.

The Bottle Creek Gold Project is located 95 kilometres north-west of Menzies in the northern Goldfields of Western Australia (WA). The mine commenced operation in June 1988 but, due to a limited gold resource, ceased operation in November 1989. Three open-pits and waste landforms, a plant site, run-of-mine pad and two tailings storage facilities were established during the operational stage of the project.

In May 1990 a proposal to rehabilitate the site was submitted by Norgold Limited to the then WA Department of Minerals and Energy (DME).

In 1992 the Minister for Mines approved a refined plan and required unconditional performance bonds to be lodged.

The mine was largely rehabilitated by 1994 but, soon after this, 300 millimetres of cyclonic rainfall resulted in significant erosion and gulying on the landforms. DME requested that Norgold undertake appropriate rehabilitation works to repair the damage caused by the cyclonic event.

In September 1996, Norgold requested that DME release the bonds. The environmental inspector raised a number of issues that required attention prior to bonds being retired. These issues included remediation of erosion gullies, reseeding poorly vegetated areas, battering-down of slope angles (on some of the remaining structures), application of topsoil to several areas, and backfilling of drillholes.

Two more joint site inspections were undertaken in October 1996 and in June 1997. Norgold was requested to submit a new rehabilitation plan to detail how, when and to what standard it would undertake the remediation works required by the DME.

In November 1997, Norgold submitted a new rehabilitation plan. The work was completed by May 1998. DME undertook another site inspection in May 1998 and identified further small works.

In November 1998, Norgold submitted a compliance review as well as a monitoring program report which included a validation of the rehabilitation and developing ecosystem using ecosystem function analysis (EFA). This monitoring system, developed by CSIRO [www.cse.csiro.au/research/ras/efa/index.html](http://www.cse.csiro.au/research/ras/efa/index.html) reports on the condition of the ecosystem by comparison of the level of

functionality displayed by the rehabilitation with a comparison from control/analogue sites in the surrounding region.

A closure inspection was undertaken in December 2000 which identified two issues that had not been resolved to the satisfaction of the DME—the potential for acid rock drainage and the presence of feral goats within the fenced area.

Rio Tinto (which acquired Norgold) investigated and subsequently addressed these issues to the satisfaction of the DME which recommended that the bonds be returned and that all tenement conditions relating to the project be deleted from the schedule of conditions attached to each tenement. In November 2001, the Minister for Mines deleted all tenement conditions and returned the bonds, confirming that Norgold had rehabilitated the site to the satisfaction of the state mining engineer.

Persistence in closure works, consultation and meeting final requirements eventually worked for Norgold-Rio Tinto. The use of a robust monitoring technique over time was able to adequately demonstrate completion criteria in the rehabilitation. This evidence was accepted by the regulator leading to final relinquishment. The regulator continues to monitor Bottle Creek Mine by conducting occasional monitoring programs with departmental officers and a Perth-based consultancy, which retrieves and analyses EFA data from the fixed monitoring transects at the site.



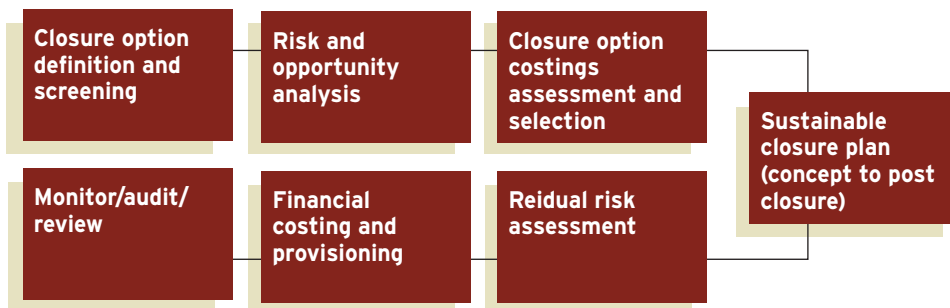
**Bottle Creek mine site before and after rehabilitation**

Further details about this case study can be found in Anderson et al. (2002).

### **2.3 Managing closure risk**

Risk management is an integral part of mine planning and management, and a risk management system can enable an operation to identify the risks and develop controls associated with sustainable mine closure and achievement of mine completion. The elements in Figure 2 constitute the basis for the risk assessment and establishment of the closure plan that will contain the risk controls.

**Figure 2: An approach to the use of risk management in closure planning**



### **2.3.1 Option definition and selection**

Option analysis of closure concept alternatives creates opportunities to explore the benefits and risks with each option in the context of the established closure plan objectives and criteria. From these alternatives, cost-effective closure strategies that meet the policy objectives can be developed and discussed with the stakeholders. It helps define, at a high level, those closure concepts which warrant more specific risk and opportunity analysis. Options need to consider a range of potential final land uses and alternatives in consultation with the future landowner or affected communities. The option analysis methodology is flexible. It should be reviewed regularly to ensure that it meets the level of detail required at any stage within the life cycle of the project.

### **2.3.2 Risk and opportunity assessment of options**

A risk and opportunity assessment is required to ensure a consistent approach to the identification and management of issues associated with mine closure. This assessment needs to consider environmental, social, economic and regulatory risks; external and internal factors, not just address the mitigation of risk (uncertainty); and should evaluate opportunities that sustainable mine closure options might present (Environment Australia, 1999). Typically, each issue (or aspect) can be assessed for its potential environmental, economic, social and regulatory risk factors. A product of this process is the creation of a comprehensive closure risk register that identifies the issues, their risks and their priority.

Mitigating unacceptable risks back to a tolerable level will involve the development of control options against each of the risk factors. These options may be used to determine probabilistic costing as a basis for financial costing and provisioning.

Following the selection of the most appropriate control option, it is possible to calculate the level of residual risk that may remain after mitigating strategies have been applied. If the residual risk is unacceptable, then further review or work programs may be required to determine a control strategy to reduce it further.

### **2.3.3 Establish closure option cost evaluation**

Cost will be a factor in evaluating the various closure options. Different closure options can be examined using an appropriate risk methodology and the relative costs and benefits of each concept can be compared.

### **2.3.4 Develop a sustainable closure plan**

After fully assessing the closure risks and opportunities, a mine closure plan (to achieve completion) can be developed to manage risks to an acceptable level and maximise strategic opportunities.

This documented plan needs to provide a suitable basis for estimating the cost of closure and should include a description of the management of the site's planned closure activities that are consistent with policy, objectives, standards and guidelines.

This plan is a dynamic document that needs to reflect the level of detail appropriate to the stage of development of the mining project. Closure plans will evolve throughout the life of a mine and are required to provide more detail as the mine nears decommissioning and closure.

### **2.3.5 Closure plan residual risk assessment**

Ideally the closure plan addresses closure risks at acceptable levels; however, there will always be a level of residual risk or uncertainty which requires further assessment and management. These include the success or failure of the chosen option, cost forecasting, and the risk that an event such as an earthquake, cyclone or unusually large rainfall may occur. For example, a particular water treatment process or dump design may have been identified to control the risks. Having developed the control (the closure plan), there will still be a residual risk that the water treatment—as planned—could fail, requiring additional measures. Failure could be due to changes in chemistry, damage from an earthquake or changing regulations that may require stricter discharge limits. Even in cases of low severity and unlikely residual risk, analysis should still be carried out from a long-term risk management perspective. A risk-based closure plan will identify and assess residual risk and the outcomes will be included into the costing methodology.

### **2.3.6 Establish a consistent financial costing and provisioning methodology**

The steps described in Section 2.3.5 provide the basis for assessing the impact of potential costs of closure on the operation or the investment that may be under consideration. Deterministic and probabilistic estimation techniques may be needed to calculate the cost of significant residual risks. The closure team will need to determine if probabilistic costing is necessary or appropriate based on the project risk profile.



Risk-based cost estimates fulfil several requirements including:

- provision of costs for making investment decisions
- costs for accounting provision
- development of a closure project budget.

Additionally, there are closure costs for government rehabilitation bonds. These costs may or may not include risk costs and may include other costs associated with the regulatory regime and execution of closure. There may be the opportunity to establish target timeframes for specific aspects of closure to achieve a stepped reduction in bonds over time as performance milestones are achieved.

### 2.3.7 Establish a monitoring/audit/review process

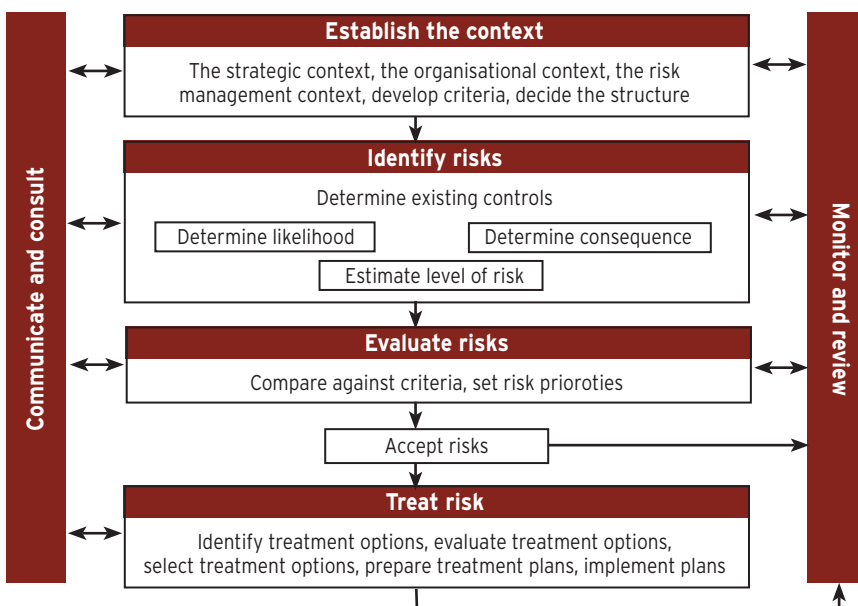
To complete the development of a risk management system for closure, it is necessary to have a process of monitoring, auditing and review that ensures the initial mine closure plan is kept updated and fit for purpose. It also enables closure planning to be reconsidered in each step of the mine life cycle to identify and accommodate changes that may have taken place over the life of the mining operation.

The initial mine closure plan may be conceptual from project concept and be steadily developed in detail through to the last five years of the project life. The plan will then improve and become more detailed as the investment matures.

It is appropriate to consider a formal update of closure plans on a regular basis to incorporate new information, assure risks have been properly evaluated and cost estimates are valid.

A summary of the risk-based closure planning process is shown in Figure 3.

**Figure 3: A summary of a risk-based closure planning process.**



## Case study: Misima Mine, Papua New Guinea

Misima Gold Mine commenced operation in 1987 and operated until 2004 producing 3.6 million ounces of gold. Final deconstruction and rehabilitation earthworks were completed in April 2005.

The closure of a large mine site can have potentially conflicting objectives such as minimising costs of closure, maximising ongoing benefits to the local community or region, and minimising environmental liabilities from the mining operation. The overall goal is lease relinquishment.

The achievement of such goals often requires compromises. Mine closure planning can be very challenging, particularly when socio-economic, cultural and political factors are included and further complications arise from stakeholder disputes over the actual detail of final asset disposition and final land use targets.

Detailed planning for the closure of Misima Mines Limited commenced five years prior to the last ounce of gold being poured. A semi-quantitative risk assessment technique (potential problem analysis (PPA)) was used in a facilitated workshop environment to gather the views of a cross-section of stakeholders for rehabilitation planning:

- an initial workshop in November 2001 identified safety and sustainability issues and hazards, and ranked and prioritised suitable control measures
- in October 2003, a further risk assessment workshop was held to review the ... detailed closure plan being developed and the identified 2001 hazards
- in May 2004, prior to actually beginning the physical demolition, a final risk assessment workshop was conducted focusing on key safety aspects of the deconstruction plan.

The key mine closure components and hazard sources identified by the PPA workshop team included:

- Bio-physical—the main identified components included open-pit voids, on-land waste dumps, stockpiles, marine soft waste dump, submarine tailings system, exploration access roads and infrastructure. The bio-physical hazards comprised physical instability, erosion and sedimentation, geochemical stability (acid rock drainage and metal leaching) and contaminated sites.
- Socio-economic—the main identified socio-economic hazards are associated with the ongoing sustainability of utilities (electricity, water, communications), social progress (health, education, justice), infrastructure (wharf, roads, airstrip) business development, food security and trust fund security following mine closure.

There is a significant interaction between the various biophysical and socio-economic mine closure aspects.

An action plan was developed and included in the site's sustainability closure plan for implementation, resulting in the following outcomes:

- successful deconstruction/demolition and earthworks completed as planned
- no lost time accidents or serious injuries
- landform use suitable for agricultural purposes
- social opportunities created with local landholder group and government managing the hydroelectric power and water system on behalf of the community
- local and provincial governments responsible for the health and medical centres and other infrastructure installed as part of the community development plan.

The ultimate success of the mine's closure is dependent on participation of all stakeholders who will actively support and help in planning the mine closure in order to achieve the company's and stakeholders' goals and aspirations. A structured holistic approach utilising a sound risk model means that all potential issues (social, environmental, safety) are identified and incorporated into the mine planning processes.



**Mt Sisa–August 1997**

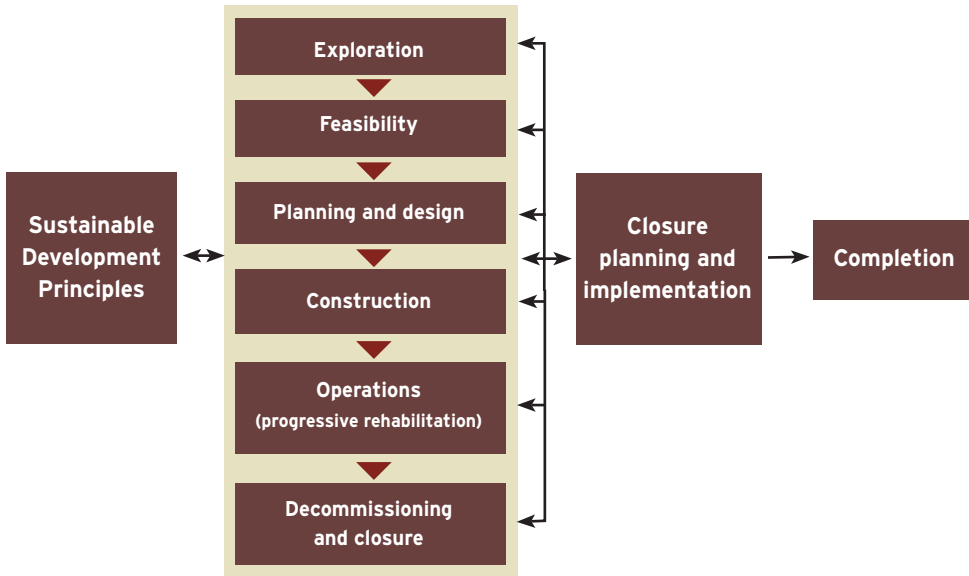


**Mt Sisa–February 2006**

### 3.0 WHOLE OF MINE LIFE PHASES

This chapter examines the relationship of closure with the various phases in the life cycle of a mining project.

**Figure 4: Phases of a mining project.**



Planning for mine closure should be undertaken progressively throughout an operation's life cycle. The amount of detail will vary and refocus on specific issues through this life cycle. In order for mine closure planning to be successful, the management team needs to ensure it is integrated early into planning rather than being attended to at the end of mine life. The initial ground work, even at the exploration phase, can impact on the effectiveness and success of closure planning. To ensure optimal results, it is critical that community and other stakeholder engagement occurs throughout the process of planning for mine closure.

### 3.1 Exploration



#### **Mineral exploration covers the initial phases of a prospective mine's life.**

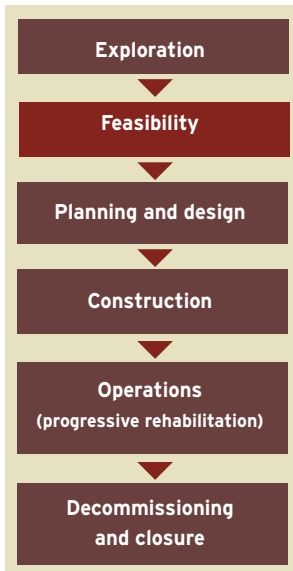
At this stage of the mining cycle, there are no guarantees that a mine will eventuate. In fact, minerals exploration rarely results in a the development of mine. However, in most cases, there will be environmental and social impacts that will need to be addressed including access tracks, drill pads, disposal of wastes, and community concerns and expectations.

It is often before or during exploration that a company's community engagement begins. In some cases, negotiations and the consent of land owners or Indigenous groups will be necessary. The quality of community engagement at this early stage is very important as it will influence future relationships.

Key activities that need to be undertaken at this early stage and which will be useful for future planning and closure include:

- develop a community engagement plan, comprising
  - community and stakeholder identification and analysis
  - socio-economic baseline study and social impact assessment
  - engagement with the local community – residents may advise how places or objects of cultural significance should be protected (refer to the Community Engagement and Development Leading Practice handbook for further details)
- preliminary discussions with community and stakeholders on the mine concept and collation of issues that need to be addressed in future environmental impact assessments (EIAs) or source impact assessments (SIAs)
- collection of early environmental baseline data including surface and ground water quality and quantity, soil types, vegetation types, meteorological data
- preliminary assessment for waste rock characterisation including testing of sulphide ore bodies for acid-based accounting and metals
- development of relationships with local stakeholders, regulators and community
- preliminary assessment of current land use and ownership.

## 3.2 Feasibility



Once a mineral resource has been identified, it is then necessary to conduct a project evaluation to determine whether the resource can be commercially mined.

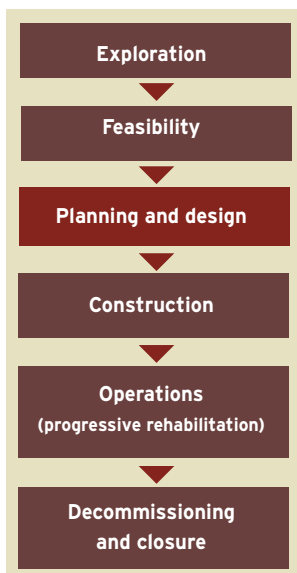
Feasibility is an integral element of the mine evaluation process and can be defined as an assessment of the economic, environmental and social impacts of the potential mining project. The objective is to clarify the basic factors that govern project success and, conversely, identify the major risks to project success. An attempt is made to quantify as many variables as possible in order to arrive at a potential value. The implications of mine closure need to be considered accurately at this stage.

Feasibility studies are required in the pre-production stages to justify the continued investment of money in the project and usually consist of a scoping study, a pre-feasibility study and final or bankable feasibility study. At this stage, the project should commission an EIA and an SIA which will provide valuable information on the baseline conditions.

In many states or territories, a preliminary closure plan is required by the regulatory authorities as part of the approval process. This plan is used to assess the project, the environmental controls required and the long-term potential liability posed by development of the mine. Typical issues that should be included in the feasibility assessment include:

- potential area of disturbance
- environmental sensitivity of flora and fauna, surface and groundwater quality
- volumes and types of wastes to be stored, including waste rock and tailings
- characterisation of wastes including geotechnical properties and AMD potential
- appropriate locations and required capacity of water storage facilities for potable consumption, process supply, and site water management
- geotechnical stability of ground surface and engineered structures
- regulatory requirements for design and closure
- proposed designs for waste storage facilities and costs to rehabilitate and close
- social and economic development and sustainability issues, such as local enterprise, post-closure use of land and infrastructure, and other community development programs.

### 3.3 Planning and design



The goal of mine planning and design is to achieve an integrated mine systems design, whereby a mineral is extracted and prepared at a desired market specification and at a minimum unit cost within acceptable environmental, social, legal and regulatory constraints. It is a multidisciplinary activity.

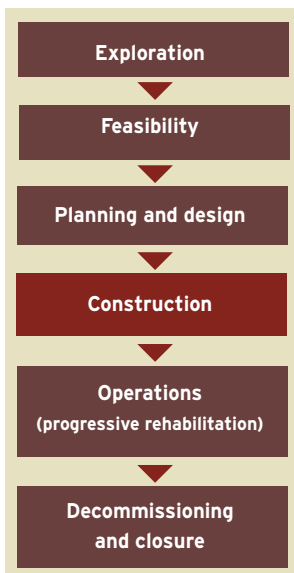
Mining engineers and mine geologists generally have the most influence in mine planning and design. They need to understand and take into account the mine closure issues, and integrate economic, environmental and social elements into the decision-making process. For example, they will need to be informed about the preliminary community expectations for post-mining land uses, the environmental quality and the aesthetics of the area. These expectations can impact, for example, on the location of access roads and waste storage facilities.

Engineers and geologists will be assisted in their decision-making through collaboration with environmental and social scientists to ensure a multi-disciplinary approach.

Decisions made during the mine planning process will have significant and long-term consequences for the mine and its environment. A risk-based approach should be incorporated into the design phase so that a wide range of business risks are evaluated, including the long-term potential environmental and closure liabilities (see Section 2.3). It is important that the lead times are sufficient to permit the collection of key information to allow sound planning decisions to be made. This is particularly important where research on rehabilitation options may be required.

Mine planners need to balance short-term cost savings against potential long-term issues. For example, a mining engineer may make the decision to mine a deposit by open-pit methods rather than by underground. This may allow quicker access to ore and therefore earlier cash flow, but it will result in higher volumes of waste and, if the waste is mineralised, it may result in later acid rock drainage issues.

### 3.4 Construction/commissioning



Construction activities at a mining project are the first to create visible changes and impacts on the environment and community. This short-term stage requires the highest level of employment, which exceeds the longer-term workforce requirements. The influx of a construction workforce can provide economic benefits to the local community, and particularly local businesses, but it can also put pressure on local services and have a negative social impact on the community.

Construction activities typically include:

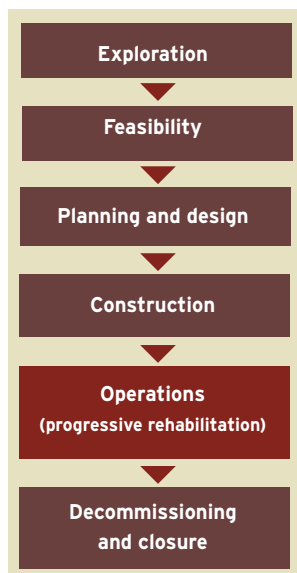
- access roads and airstrips
- construction and accommodation camps
- power supply (electricity, gas or diesel)
- fuel and chemical storage facilities
- water supply
- process plant
- workshops and warehousing
- contractors lay down areas
- offices, change rooms
- crushing plant
- tailings storage facilities
- waste rock, low-grade and other dumps, and stockpile preparation.

It is essential that construction contractors and personnel understand the implications that their activities may have for the eventual closure of the mine. Mines can close during the commissioning and construction stage due, for example, to budget overruns. Therefore activities disturbing the site should be kept to a minimum during this phase. It is also important that local landowners and the local community are not unnecessarily inconvenienced at this time and that the foundations for long-term relationships are built. During this phase, planning and design decisions can have long-term consequences for the environment, future land uses, community health and safety that will impact upon the mine closure and completion process. For example:

- poor foundation construction for a tailings dam or water storage ponds can lead to exacerbated long-term seepage and potential groundwater contamination
- waste rock dumps designed to handle sulfidic waste need to have appropriate low permeability foundations and/or acid consuming material placed as a basal layer
- poor erosion controls during construction can result in increased sediment loads to water courses during rainfall events
- proper storage and handling of fuels and lubricants, and sound workshop management can reduce long-term contamination from spillages
- proper identification and handling of topsoils and other growth media, and control of dusting from these stockpiles, can assist immediate and long-term environmental management.



### 3.5 Operations



The operational phase of a mine can extend for many years – typically from five to 20 and, in some cases, more than 50 years (for example, coal and bauxite mines). During this period there will be operation changes, plant expansions and progressive rehabilitation. There could also be changes in ownership with potentially different management approaches.

In continuing to refine the mine closure plan, the company needs to focus on the long-term goals and policies. All activities should be directed at supporting these long-term goals. Sites should be progressively implementing mine closure and completion measures during the operational phase. These include the allocation of financial resources and a team of appropriately experienced people, and engaging community and other stakeholders in the closure process.

The operations phase can be further divided into three stages—operations, mature operations and pre-closure planning:

- operations commissioning stage – the period after construction which can typically include initial commissioning, start up and pre-stripping for pits, construction of waste rock dumps and tailings storage facilities
- mature operations stage – the mid-mine phase where most of the disturbance has taken place and the mine is in steady operations
- pre-closure planning stage – this may be five years or more before known ore resources are exhausted.

### 3.6 Decommissioning and closure



Closure involves the implementation of the closure plans developed in the earlier stages, the conduct of the necessary investigations and studies to identify potential contamination, and confirmation that the agreed outcomes and criteria have been met.

Activities at this stage will include:

- demolition and removal of infrastructure
- reshaping of remaining mining landforms
- completing the rehabilitation and remediation processes
- monitoring and measuring the performance of closure activities against the agreed standards and criteria
- inspections, consultation and reporting to stakeholders on progress
- progressive community and government sign off.

The following section describes in more detail the various actions required in closure planning and implementation, leading to mine completion.

## Case study: Timbarra gold mine, New South Wales

The Timbarra gold mine is located 30 kilometres east of Tenterfield, New South Wales. Ross Mining commenced development in May 1998 as a small gold heap leach operation (86 hectares), but it was prematurely closed six months later, after producing 15 000 ounces.

The mine attracted unprecedented opposition from non-government organisations and anti-mining groups from its inception, due to the operation's disturbance of the upper catchment area of a Clarence River tributary. Several legal challenges were launched against the company in the NSW courts between 1998 and 2001.

Mine closure planning commenced in late 2000, when Delta Gold (the operator) decided to proceed with an independently facilitated engagement process with a wide range of stakeholders, including project opponents on the rehabilitation of the mine.

In 2001, there were two facilitated meetings on the site, where stakeholders could express their outrage over historical experiences at Timbarra. This included the view that sites of high environmental and cultural value had been desecrated. There also were deep concerns over the perceived inadequacy of previous scientific studies and the approvals process.

To counter the expectation that the company would dominate the meetings, the invited facilitator was an opponent of the development and a spokesperson from the Lismore Rainforest Information Centre.

The stakeholder identification process and initial consultation culminated in the creation of the Timbarra Closure Focus Group (TCFG), whose aim was to facilitate and communicate rehabilitation expectations and desired processes for mine closure. TCFG representation included government authorities, non-government organisations, landholders, Aboriginal communities and other interested parties and the company. CSIRO was invited to provide an independent specialist peer review of site rehabilitation proposals and to listen to stakeholder concerns.

The TCFG raised a number of technical issues that required resolution so they could be addressed and included in the closure plan. A number of studies were initiated to support the closure plan. These included:

- design of a sedgeland basin to reduce the concentration of nitrate (which posed a threat to frogs) draining from the re-profiled heap leach pads
- recreation of habitat for rare and threatened fauna species
- installation of bat and bird boxes to enhance habitat creation.

The findings of these studies were used to plan the initial rehabilitation concepts, including proposed landform shapes and revegetation objectives. The TCFG critically reviewed the concepts during 2002.

A draft mine closure plan was circulated to all TCFG members prior to finalisation, and exhibited publicly. Submissions received from the public were reviewed, negotiated and an addendum to the plan developed. This was then approved by the NSW Minister for Mineral Resources in November 2002. The plan formed the blueprint for site rehabilitation works, which were completed in September 2003 at a cost of \$2.6 million.

The 2001 consultation process resulted in reconciliation between various conflicting groups. Instrumental to this was the mine's new owner, which had a different approach to community relations. TCFG was able to move from a state of conflict to resolution and partnership, to achieve sound mine closure. The lessons were clear:

- community and other stakeholder views, are essential in planning mine closures and should be pursued through formal processes such as community closure focus groups
- it is important to listen to protagonists' views and address each issue
- in many circumstances, input from environmental groups can result in better managed mines that pose less risk to the environment
- collective knowledge can help solve or address issues of common concern
- use of a facilitator
- engaging in (and resourcing) conflict resolution processes rather than avoiding conflict.



**Reconstructed wetland basin, Timbarra gold mine**



## 4.0 PLANNING DURING OPERATIONAL PHASE: A MORE DETAILED LOOK

### 4.1 Operations commissioning stage

#### 4.1.1 Baseline data

Critical to the operation is the collection of relevant social and environmental data which can assist the decision-making process through the operational life and into closure. A sound pre-mining database will usually be used to set the license conditions for water, flora and fauna and also become the 'closure criteria to be met' at the end of a mining operation. Environmental data collected as part of the feasibility phase can be presented to meet the approval process. It is important to continue collection of vital data and enlarge the database to cover the spatial and temporal variations observed in nature. These data will enable an operation to incorporate natural variations into the setting of trigger values that could indicate environmental harm may be occurring from the operation. Social data will inform the development of the appropriate community and other stakeholder engagement strategy.

Collecting a set of baseline data enables the operator to establish a regional context to the potential impacts of the operation. Assessment and reporting of cumulative impacts should also be completed.

#### 4.1.2 Characterisation and selective placement of materials

Key elements of a successful progressive rehabilitation plan include:

- the comprehensive characterisation of the properties of soils, overburden and mineral processing wastes to determine their capacity to support plant growth and their potential to have adverse impacts on water quality
- the segregation and selective placement of these materials to ensure creation of a favourable medium for plant growth across the post-mined landscape and the protection of water resources.

Characterisation of soils and overburden should start as early as the exploration phase and continue through the pre-feasibility and feasibility phases as a basis for mine planning. The requirement for characterisation continues during the operation of the mine, particularly where the ore grade and mine plan change in response to altered market conditions.

Comprehensive characterisation of soils, overburden and wastes provides the basis for rigorous segregation and selective placement of materials to achieve a sustainable vegetative cover and to prevent contamination of surface and groundwater resources.

Except in a limited number of circumstances, establishment of sustainable ecosystems after mining generally requires the conservation and replacement of soil resources over the mined area. Segregation and selective placement of overburden layers is practised to bury material which is adverse to plant growth or which may

contaminate surface or groundwater supplies and to salvage materials that will assist in the rehabilitation program.

It is important that experienced personnel are involved in classifying the various waste rock types and in overseeing their removal and placement during waste rock dump construction. Failure to maintain quality control in this phase of the mine operation can jeopardise environmental protection – during operations and following closure.

In the case where characterisation of tailings shows that plant growth and groundwater quality may be detrimentally affected, there may be the potential to produce less toxic tailings through changes in the design or operation of process plants, such as the removal of sulphidic minerals which are capable of producing acid with consequent increase in soluble metal content.

Additional information on the characterisation and selective placement of materials is given in the Leading Practice handbooks: Mine Rehabilitation and Managing Acid and Metalliferous Drainage.

### **4.1.3 Education and training**

It is important to educate mine contractors and personnel about what is required in relation to design, placement of soils and waste rock. It is difficult to encourage contractors and personnel to follow the design if they are not told the requirements and do not understand the logic and reasoning behind the process. An education/training program should be developed that explains the long-term mine closure goals, and the reasons why materials are segregated and potential long-term impacts on the environment and closure.

Empowering the workforce to take responsibility for material segregation, placement, handling and data recording will make tracing of records and management of problematic wastes much easier for future managers. Ideally the program should be developed and included in the systematic training programs established at the mine. Regular reviews and rollout, especially to new contractors and employees, is critical for its success.

The commencement of a new operation is the ideal time to establish the basic environmental ground rules for all activities on the site through staff education and then enforcing environmental management systems and protocols. These would typically deal with aspects of operation that affect closure and would include incident reporting, containment of chemicals and other materials, measures to control the spread of weeds, feral animals and diseases, and protocols for dealing with and communicating with community and government. Each of these initiatives should be a critical item to be managed by senior staff to ensure effective acceptance and implementation across the operation.

### **4.1.4 Health and safety**

Mining and minerals processing operations may have significant adverse impacts on the health and safety of employees and local communities if the hazards are not quantified and then proactively managed through the mine life cycle.

The environmental release of hazardous substances can cause toxic and long-term chronic health effects for employees and for communities close to, downwind or downstream from operations. It can also compromise environmental values that are critical to the long-term sustainability of local communities, such as food and water supplies.

A key objective of successful mine closure is to ensure that the future public health and safety of the community is not compromised. The mine closure phase can also introduce increased safety risks to employees, who—faced with mine closure and consequent loss of employment may have reduced motivation and morale, which can lead to workplace safety issues. Affected communities, non-government organisations, scientists and the medical community are demonstrating growing interest in public health and safety issues related to the mining industry, and have high expectations on industry performance. These emerging trends demonstrate the importance of mining companies developing proactive engagement strategies with employees, local communities and other stakeholders on health and safety aspects of the closure process.

#### **4.1.5 Financial assurance**

Accounting for the cost of mine closure is now standard practice and has been driven by changes in accounting standards over recent years. Australian companies are required to comply with Australia Accounting Standards Board 137: Provisions, Contingent Liabilities and Contingent Assets. The costs for mine rehabilitation and closure are recorded as a liability in a company's balance sheet. The standard requires a company to provide for the costs of closing a mine, based on the actual disturbance at the reporting date. Mining companies listed on the US Stock Exchange (this includes many Australian mining companies) are required to comply with FAS 143: Accounting for Asset Retirement Obligations.

The new level of accounting scrutiny puts the emphasis on the mine owners to provide transparent, robust costs for mine closure and Element 6.5 of Enduring Value (MCA, 2004) provides guidance on this issue. The funds will be available to guarantee effective mine closure and rehabilitation so that ongoing environmental problems are avoided. Effective implementation of policies on financial assurances has the potential to reduce the scope for public criticism of industry practices.

Governments and mining companies have an interest in agreeing on realistic forms and amounts of financial assurances. They need to be effective in terms of environmental protection but should not unduly depress capital availability or damage the investment climate. This entails agreeing on the appropriate financial instruments and the expected standards of rehabilitation before a major mining project is approved and reviewed through the project life.

The standards of rehabilitation required of operators will clearly affect the cost of the work and the amount of financial assurance required. Although mining is considered a temporary use of land, a requirement to return the land to its pre-disturbance condition, or to a condition permitting resumption of its earlier use, is not always achievable. Policy makers and industry need to develop practical criteria for assessing the adequacy of rehabilitation efforts.

The impacts of financial assurance requirements on existing operations also need to be considered. The challenge for governments is to apply these requirements in such a way that they contribute to the goal of environmental protection but do not force existing operators into premature closure. The timing and nature of new requirements, as well as transition provisions, require careful consideration.

In Australia a number of financial instruments have been used over time. The change in approach reflects a maturing of government's management and regulation of the industry and the environmental performance of the industry.

Initial assurances were often inadequate or constrained in the amounts that were sought due, in large part, to a lack of knowledge of the true costs of rehabilitation and closure. In the past, States used a mix of sureties, securities, cash deposits and bank guarantees. Current practice favours the use of unconditional bank guarantees with the amount of assurance based on a calculation of the true cost of rehabilitation and closure. Some states and territories are investigating the opportunity for the use of insurance bonds once the long-term security aspects can be dealt with.

### **Tax deductions for mine site rehabilitation**

The *Australian Tax Act* contains specific deduction provisions for costs incurred in rehabilitating a former mine site. A deduction is allowed for expenditure incurred, provided the rehabilitation is:

- on a site on which a person carried out mining operations, conducted exploration or prospecting
- conducted ancillary mining activities of a mining building site.

Central to this deduction provision is the concept of 'mining site rehabilitation'. It is defined by the *Australian Tax Act* as an act of restoring or rehabilitating a site, or part of a site to, or a reasonable approximation of, the condition it was in before any of the relevant activities took place. Partial restoration or rehabilitation still qualifies for the deduction even if the taxpayer does not complete the work. The deduction for rehabilitation expenses is limited to activities which return the land to a standard suitable for its previous use. Therefore expenditure incurred on improving the land for a different future use (such as agriculture) is not deductible.

As the *Australian Tax Act* is under continuous review, companies should seek advice with suitably qualified taxation professionals regarding mine closure activities.

### **Provisioning**

A provision is raised for the anticipated expenditure to be made on mine rehabilitation and closure costs. The amount of the provision is recognised as the best estimate of the expenditure required to settle present obligations, discounted using a pre-tax discount rate that reflects current market assessments of the time value of money and those risks specific to the liability. The best estimates of expenditure are based on what a company would rationally pay to settle the obligation or transfer to a third party at the time. Companies should seek advice from financial professionals on how to address these accounting issues.



## Case study: Calculating a realistic security bond

During the 1990s, a number of mine operators in NSW became insolvent and mining leases, along with the closure and rehabilitation liabilities, were passed back to the government. In many cases it was found that the security bond held by the government represented only a small portion of the actual amount required to effectively close the operations to appropriate standards. Accordingly, where no alternative was identified, these mines were managed by the Department of Primary Industries – Mineral Resources (DPI-MR) as part of their Derelict Mines Program (DMP). Even when supplemented by DMP funds, there was frequently insufficient funds for full or even adequate rehabilitation.

Derelict mines continue to burden NSW taxpayers as well as being a public safety and environmental risk. Their legacies arguably represent a risk to the mining industry's public licence to operate and to the image of sustainable mining practices throughout Australia.

With the aim of investigating potential underlying causes for the failure of the government to hold sufficient security for closure, the DPI-MR commissioned URS to undertake a study into its security review process including benchmarking of processes against other agencies in Australia and around the world. URS found that, in general, agencies did not hold sufficient securities to cover potential mine closure liabilities.

A key recommendation of the review was that mine operators should have the responsibility for 'self assessment' of the total costs required for rehabilitation and closure. This would enable operators to take a more active role in the calculation for their individual security bonds and in consultation with the DPI-MR, ensure that a more accurate calculation of security bonds is made.

Consequently a rehabilitation cost estimate tool was produced by URS and GSS Environmental (GSSE) to provide a simple, transparent and consistent approach for all NSW mines to use in their estimation of closure liabilities. The costs calculated using the tool would then form a guide for the DPI-MR to use in security bond calculation.

A key approach taken in the development of the tool was to separate mines and other extractive industries into seven categories based on the nature, size and scale of operation. Operators choose the most suitable category for their site, and relevant spreadsheets are automatically generated that provide rates for the most likely closure activities relevant to that site.

Once the category is selected, the tool divides the mine into separate areas that have similar rehabilitation needs for post-mining land use. These areas are called 'domains' and they typically include areas such as infrastructure, run-of-mine, tailings storage facilities, overburden and waste rock dumps, active operational areas and voids, and surface water structures.

The below picture is an example of a typical mine layout showing the allocation of domains.



### Typical mine layout

For each domain area, a number of generic activities are listed as line items within the tool. These line items generally describe what activities are needed within the domain in order to meet closure requirements for a given site.

The operator needs to input unit amounts (typically linear-based and area-based information) for the relevant activities, and then costs are generated automatically.

There remains an onus on the operator to include all relevant costs related to closure, whether prompted by the spreadsheet tool or not.

The tool is now being used by the DPI-MR as a basis for closure cost estimation in NSW and is being adapted for use by the Victorian DPI in its management of mines and extractive industries. Other states and territories have also expressed an interest in the tool.

Regular use of the tool is expected to lead to the early identification of closure liabilities and proactive management of site operations to reduce these liabilities.

## 4.2 Mature operations stage

### 4.2.1 Mine planning design – developing the mine closure plan

The mine closure plan is a living document that will be continually reviewed and revised over the mine's life. The level of detail will vary as the mine matures and knowledge is gained on the significant issues to be addressed in the mine plan and options for dealing with them through closure. A typical approach to developing a mine closure plan is to segregate the mine into specific areas or domains. Each domain should be treated as a separate entity for detailed work plans, but within an overall plan which addresses the integration of the domains. For example, at a typical open-pit or underground mine, the site may be segregated into the following domains:

- ore processing – plant site
- shaft hoisting and headframe (for underground mines)
- workshops and hydrocarbon storage areas
- waste rock dumps (mineralised and barren)
- tailings storage facility
- process water and raw water dams
- pits or voids (underground declines)
- access roads, exploration tracks and service area infrastructure
- camps and accommodation areas.

Each site is unique and the specification of domains will depend on the final plans for landform, the works to be done and the potential long-term risk to the environment. In large multi-pit mines developing satellite ore sources, there may be up to 100 domains, as each area (for example waste rock dump, pit, plant site and workshop) is given its own unique domain and project status and managed as an individual entity.

### 4.2.2 Domain requirements

For each domain, a detailed closure plan will need to be developed. However, the plans for each domain should be integrated into an overall plan to address common issues such as the drainage pattern. These domain plans would normally consist of the following:

- area of disturbance
- review of legislation and regulatory requirements or license commitments
- identification of environmental hazards and risk assessment
- development of options for each major issue or hazard identified within the domain
- plan for deconstruction and removal of infrastructure
- understanding of likelihood for short-term and long-term contamination and management of identified contaminated wastes

- agreed final landform, landscape design and final land use
- earthworks plan required to create final landform
- erosion controls and drainage plan
- capping or other control mechanisms to manage potential contamination
- rehabilitation plan, plant species required, seed versus tube-stock, fertiliser requirements
- rehabilitation monitoring requirements to meet long-term sustainability targets or objectives
- water (surface, groundwater) monitoring program to meet site or off-lease license conditions
- cost estimates for deconstruction, earthworks and habitat reconstruction, revegetation, care, maintenance and monitoring.

While this list is very comprehensive and will be unique for each domain, there are a number of repetitive tasks that are best incorporated into an overall site plan. These typically include the overall monitoring program across all domains and involve water, vegetation performance, erosion rates and other licensed activities.

Many companies use computer programs linked to GIS and other mapping tools to accurately represent the land under management. By overlaying digital terrain models and using 3D software, actual as-built features can be shown. Constructed landform designs can also be easily created and displayed. This can aid the mine planners and environmental staff to design cost-effective landforms that meet the closure goals. The programs also provide visualisation of progressive rehabilitation and final landforms for community stakeholders, enable accurate volumes of material to be calculated and allow the overall costs for the work to be estimated. This methodology is becoming more refined and as, the financial bodies require greater transparency and a demonstrated systematic approach to closure costing, this should become standard practice in the future.

### **4.2.3 Establishment of a closure committee**

The establishment of a consultative closure committee, integrated into an overall stakeholder engagement strategy, can be a useful forum in which long-term objectives can be discussed with a wide range of stakeholders and community representatives. By involving people with a particular interest in closure issues early in the planning processes, operations can incorporate community input into the overall site plans.

These forums have shown to be a powerful means of engaging stakeholders and demonstrating to regulators that there is community support and input into the overall plan. The closure committee can also have a formal role in the sign-off process (see Chapter 5).

## Case study: Beenup

The Beenup minesite is located in the South-West of Western Australia, near the confluence of the Blackwood and Scott Rivers, on the Scott Coastal Plain. Land use within the Scott Coastal Plain area primarily consists of pasture production for beef and dairy, silviculture and some horticulture.

Mining operations for minerals sands at Beenup commenced in January 1997 and closed in February 1999 leaving a large expanse of deep water, a number of temporary and permanent dams and stockpiles containing mine waste consisting of cleaned sand, fine clay and varying levels of pyritic mineral.

Difficulties were encountered during mining with the predicted settling and consolidation rates of the fine clays not being achieved. The pyrite burden associated with the mining operation would also be a significant factor in determining the rehabilitation methods. At the time of closure, a total area of 336 hectares of land had been disturbed. The majority of the disturbance being associated with the dredge pond and above ground storage facilities.

One of the initial steps undertaken by BHP Billiton in the preparation of the Rehabilitation Plan for Beenup was to develop an overall closure philosophy. BHP Billiton saw itself as a temporary resident and recognised that the permanent community would be critical to the success of the project. To this end, the company set out to develop a flexible plan, which fostered continuous improvement. The company was fortunate to have an active community consultative group in place at the time of the mine closure. Membership of the Beenup Consultative Group (BCG) is comprised of Shire representatives, landowners, and business and conservation group representatives.

To assist the community consideration of various rehabilitation concepts, BHP Billiton prepared visual impressions of preferred options. The BCG played a significant role in the selection of the preferred rehabilitation option from a number of options put forward. Following option selection BHP Billiton commenced preparation of a detailed Rehabilitation Plan for consideration by the Western Australian Government. The BCG also assisted in identifying key issues to be dealt with in the implementation process and provided a communication channel for Government to obtain feedback on aspects of the plan.

The key issues identified were:

- water quality released from site
- security of acid soils
- impact on ground and surface water
- long term rehabilitation of the Mine Development Storage Area
- impact on hydrological regime
- rehabilitation of trial mine areas
- landscaping and land use of the area.

As an outcome of the initial consultation, a preferred concept was selected which included backfilling the dredge pond with mined material creating wetlands surrounded by native vegetation and pasture. Selection of this concept provided direction for development of the detailed Rehabilitation Plan and became widely accepted by Government and the BCG.

In 2001 the BCG set up an independent audit on the progress against the Rehabilitation Plan based on a protocol which they developed. This process facilitated continuous improvement and enabled the local community and company the opportunity to ensure ongoing implementation of the latest advances in rehabilitation technology, so that the end result will be acceptable to future generations, far beyond the completion date.

Since completion of the earthworks and revegetation activities, both Government and community maintain confidence and ownership in the progress of the rehabilitation project and the community are well familiar with and speak with some authority on the principles and progress towards sustainability.

The following were key to the success to date of the Beenup closure project

- Early acceptance of the company's temporary residence
- Early stakeholder involvement
- Immediate community consultation once closure was announced, as a result of the active community consultative group already in place
- Maintenance of long term stability in the membership of the community consultative group
- The need for detailed disclosure and understanding between the company and community
- Implementation of an independent community directed rehabilitation audit
- Use of well recognised consulting firms for technical direction
- In the event of individual concern and grievance within the consultative group, in-depth investigation and review of alternatives was undertaken in an endeavour to identify causes and develop measures to alleviate these concerns.



**June 1999**



**November 2002**

#### **4.2.4 Closure options—the need for research and trials**

In many cases when the mine closure plan is being developed, there may not be a clear methodology that can be applied to meet the closure goals, for example, developing a capping design for a waste rock dump to minimise oxidation and generation of acid rock drainage.

In these circumstances, specialist expertise is needed to develop a range of potential designs that could meet the long-term objectives. Evaluation of each design should include the materials to be used for the cover construction, modelling of the various inputs and outputs and prediction of long-term performance. The next steps are usually to develop trial cover systems – using the preferred two or three designs of lowest assessed risk – and monitor performance.

Cover design performance should be evaluated for at least three years. Data collected can be used to recalibrate the model and influence a final design for closure of the waste dump. In particular, the occurrence of extreme rainfall events or higher than average wet years, provide opportunities for rigorous testing of the design.

Another example where field trials are desirable is the revegetation of problematic soils or spoils. Many of the overburden soils mined in the coal fields contain sodic material, which is highly erodible, but also has poor nutrient and growing characteristics. Field trials and combinations of additives, such as fertiliser, organic material, lime and fly ash may need to be needed to establish a growing medium that will encourage revegetation to a standard appropriate to the post-mining land use.

Research and trials can take several years to establish, monitor and modify before acceptable outcomes are achieved. It is critical that these trials are established long before the mine closes so that the knowledge from the trials can be incorporated into the final mine closure plans.

#### **4.2.5 Progressive rehabilitation**

The ability to progressively rehabilitate sections of the mine site as they become available is an important way of reducing the long-term closure liability and is encouraged by most regulatory authorities. Actively rehabilitating areas during the operational stage can usually be cost-effective. Earthworks can be completed when equipment is available or when contractor equipment is mobilised to a site for other jobs. The contract can often be extended to undertake the rehabilitation works, saving on mobilisation.

The most cost-effective earthworks can be completed when they are integrated into the mine plan. For example, when waste rock is being hauled out of a pit and placed into a dump, the waste rock could be transported to an adjacent dump that needs a rock mulch cover over the final landform to reduce erosion. Rather than double-handling the material, the incremental initial cost in transporting it the extra distance is more than compensated by the resulting cost-effective and timely progressive rehabilitation. Benefits of progressive rehabilitation include:

- reduction of the overall un-rehabilitated ‘footprint’ of the mine
- an ability to trial various options and demonstrate rehabilitation outcomes to wider community

- showing commitment to stakeholders and employees that the mine has an active mine rehabilitation program
- reduction of the overall closure costs
- reduction of the risk of failure and ultimate liability
- reduction of the 'rehabilitation bond' posted with regulatory authorities.

Mining companies are facing increasing pressure from regulators to undertake progressive rehabilitation and reduce the outstanding backlog of works. The Queensland Environmental Protection Agency has recently released a guideline and changed the regulations. Companies now undertaking progressive rehabilitation are provided with surety regarding completion of rehabilitation that meets the agreed closure criteria.

#### **4.2.6 Monitoring standards and performance**

While successful mine closure requires that good rehabilitation standards are achieved, this must be demonstrated and reported to regulatory authorities and other stakeholders (Enduring Value Element 6.3 and Principle 10). The definition of closure standards and criteria, and the ability of industry to actually achieve these standards, has been a major issue in the past. The success of any policy framework relies on all participants agreeing on the standards and outcomes being sought and that they are developed through an open and transparent process. It is useful to divide these outcomes into milestones or steps that can be achieved progressively over time. The program will enable the standards and performance to be assessed.

The program must take into account the practicalities of monitoring, cost and safety and, where possible, be based upon proven and widely accepted techniques. A good program will seek opportunities to involve the local community, including Indigenous people, in monitoring activities. This approach provides employment and captures local knowledge on topics such as the local environment, biodiversity and cultural issues.

Typical monitoring programs that support a mine closure program can include:

- baseline monitoring in the early mine life phases. This defines the values that need to be protected or re-established. For the purposes of rehabilitation, it should include the identification and establishment of unmined reference areas during pre-mining mapping and surveys.
- monitoring, recording and understanding of all potential impacts during the operational phase of mining.
- documentation of the rehabilitation operations carried out—to confirm that agreed procedures have been implemented and to assist when interpreting the findings of later rehabilitation monitoring results.
- Initial closure monitoring conducted within one to two years of rehabilitation, to evaluate initial establishment success.
- long-term monitoring, commencing usually two to three years after rehabilitation, to evaluate the progress of rehabilitation towards fulfilling long-term land use objectives, and determine whether the rehabilitated ecosystem is likely to be sustainable over the long term.



- Post-lease relinquishment monitoring to confirm that the sustainability of the post-mining land use under the applied management regime. Who is responsible for, and the extent of, this monitoring will depend on a company's commitments and obligations, and the information needs of stakeholders. Responsibility for post-lease relinquishment monitoring will need to be determined as part of the mine closure plan.
- Assessment of data to identify problems and develop solutions during progressive rehabilitation. Research and field trials should be undertaken to determine which techniques work and which do not. This approach is central to the principle of continuous improvement. Usually, research on rehabilitation operations will require technical experts from universities and other research institutions to address specific areas like soil development, nutrient cycling, fauna monitoring, timber and agricultural productivity.

Stakeholder engagement is an important tool in closure planning. Environmental closure plans only have relevance in the community and context to which they are designed and communicated. By measuring and monitoring community engagement and development prior to, during, and post-closure, companies will be provided with an opportunity to:

- gain feedback from all stakeholders regarding options and alternatives
- build relationships of trust or repair fractured relationships
- maintain the social licence to operate
- help mitigate dependency
- benchmark closure/community plan effectiveness
- enhance the potential for sustainable mine closure (completion).

If the monitoring and measurement of environmental accountability and of stakeholder engagement and community development are performed as interdependent considerations of mine closure, the process of relinquishment will proceed more smoothly. Further details on stakeholder engagement and community development are provided in the Leading Practice Sustainable Development handbook Community Engagement and Development.

#### **4.2.7 Review of closure strategies and plans**

Throughout the mine's life, closure strategies should be regularly reviewed to ensure they are appropriate, address the major issues for closure, and remain aligned to community expectations and regulator requirements. As part of the mine's change management system, alterations to the mine operating plan, expansions, new pits, waste dumps or a tailings storage facility, or changes to the operating process should trigger a review of closure risk and review of the plan. Using the risk-based approach outlined in Chapter 5, a review of the underlying risks to the business and closure should be undertaken on a regular basis to confirm that the controls are remain adequate and the risk exposure has not materially changed since the last risk review. The collection of appropriate and accurate data through monitoring programs is critical to this process and will assist managers in decision-making.

The review process provides an ideal opportunity for engagement with stakeholders through community committees and the building of relationships that develop trust and confidence in the operation.

#### **4.2.8 Annual review of closure plan**

An annual review of the closure plan is standard practice for most companies and also the regulators as they require annual statistics on areas of disturbance, areas rehabilitated in previous year and areas yet to be rehabilitated (Enduring Value Element 6.3 and Principle 10). In addition, the company and relevant stakeholders usually require a review of the closure cost calculations (liability) as part of annual accounting policy and procedures. The closure plan is a key reference document during this process, as it demonstrates to accountants and auditors the philosophy and strategies to be undertaken should the mine close. The level of detail should reflect the complexity and the maturity of the site.

### **4.3 Pre-closure planning stage**

#### **4.3.1 Finalise closure plan**

At a point in a mine's life, exploration will be unable to define further reserves or resources, and mine management will be able to define a likely closure date. Mine management should take the existing mine closure plan and develop the final plan that covers all aspects of closure including the plans for the maintenance, demolition or removal of infrastructure; rehabilitation; safety and social obligations; release of staff and retention of key people.

Key people involved in this plan should include the management team, environmental and community relations staff and an experienced mine planner with project management skills. The final closure plan should also ensure that exit strategies are in place for all community development programs (Enduring Value Element 9.3). There will also be a role for the community and other stakeholders to provide input into the final plan through the appropriate engagement strategy devised for this phase of the mine cycle. Using a dedicated planner enables tasks to be scheduled and incorporated into a master plan.

Ideally, the team will include people experienced in change management who are able to embrace change and work with a wide range of employees, contractors, regulators and other people involved in the closure process.

As previously discussed, most mines typically divide the site into a number of domains. A detailed plan needs to show the tasks to be undertaken step-by-step and also the resources required to do the job (equipment, people, supervision and contract resources). The plan will need to consider other essential services like power, water, maintenance workshop availability, as their removal could impact on proposed deconstruction schedules. Often portable generators and mobile workshops need to be hired as key infrastructure is removed and power is still required for maintenance and deconstruction equipment.

For example, at the Kidston gold mine in north Queensland, the first project plan had more than 3000 jobs (with multiple tasks) that were going to take more than 2.5 years to complete. The closure planner was able to reduce the time back to nine months by actively rescheduling all resources, including equipment and personnel.

### **4.3.2 Minimise the potential environmental liability**

As closure approaches there is an opportunity to reduce the environmental liability by managing the waste streams. There may be an opportunity to process sub-economic ore through the plant that would not normally be processed but, if left unprocessed and exposed in a stockpile, could cause acid rock drainage and cost more to rehabilitate than processing at a loss. Other examples could include:

- Processing oxide material through the plant and sending the oxide material to tailings to create a benign layer, or cover, over more reactive tailings. This may be a cost-effective solution, rather than the traditional truck and shovel placement of benign solids over a tailings impoundment which may require material sourced from outside existing disturbance.
- When undertaking the inventory of sites to be rehabilitated, each pile of rock or tailings should be looked at as a possible resource that could be used to rehabilitate another area. By considering the potential risk to the environment of each waste pile, creative opportunities may arise where a waste material may be used to minimise a risk factor on another waste pile, such as a pile of coarse durable waste rock used to rock armour another pile of proven erodible soils. The durable rock may also be seen as a valuable resource by the local council for road construction works, providing it is chemically benign.
- Placement of highly reactive sulphide material in the base of a pit or back underground where it will be submerged under metres of water to stop oxidation reactions will be a superior outcome compared with construction of an engineered soil cover that may fail in the future. The short-term, higher cost may be more cost-effective in the long-term if, for example, a water treatment plant is required to capture and treat poor quality effluent for many years.

The use of risk management principles (Section 2.3) in assessing options and costs is a sound way of justifying options to management and selecting the most sustainable options to reduce long-term environmental liabilities.

### **4.3.3 Value the assets and plan for the asset sale/transfer process**

Before assets are sold, they need to be valued and a detailed itemised inventory completed. This is a significant task for most mines and should be started several years before closure. Preliminary work should commence using the asset register; however, these registers are usually incomplete. Spare parts and maintenance records for mobile and fixed plant need to be included, as they can 'value add' to the sale.

Dedicated maintenance staff familiar with the equipment can assist the sales brokers by providing a reliable inventory of plant and equipment.

The sale process needs to be established by mine management.

There are three main types of sales approaches used; prior sale agreement usually through a tender arrangement or equipment broker, individual items sale through advertisements, and general public auction. It is usual to engage an experienced equipment sales broker and auctioneer, who will act on the company's behalf to sell all plant, buildings and equipment on a commission fee contract. Expected returns for a well-used plant and mobile equipment is 12 per cent to 20 per cent of new price.

There may also be the opportunity at this stage to transfer some assets to local communities or local businesses and not to demolish infrastructure that may be of assistance to the local community. For example, demountable buildings, furniture and equipment, fencing or a water bore may be highly valued by the local community. Further, the community or local council may also request that access roads and airstrips are not demolished. This will require negotiations and planning to ensure that there is a clear transfer of assets or infrastructure that does not impose any further liabilities for the company.

#### **4.3.4 Developing a deconstruction plan**

Development of a formal deconstruction plan is usually overlooked and not properly costed. Many mine closure plans assume the value of the assets being deconstructed will offset the deconstruction costs and be cost neutral. The new accounting standards, AASB 137 and FAS 143B, require companies to generate the full deconstruction costs.

In order to prepare a deconstruction plan, suitable civil engineering deconstruction experts or cost estimators should be engaged to provide advice on the most cost-effective way to safely remove the plant.

The original engineering drawings (blueprints) and subsequent plant modification and component specifications are critical for engineers during this process. Decontamination of hazardous chemicals used during the process needs to be identified and a decontamination and disposal process established.

The sequence of deconstruction is important, especially if the plant is to be sold, broken down into transportable loads and then rebuilt at another location. Consideration needs to be given to component weights for crane lifts and road transportation weight limits. Specialist transport and heavy haulage experts will need to be engaged to advise on large component transportation, such as SAG and ball mills and haul trucks, although this usually becomes the responsibility of the purchaser.

The deconstruction process will generate considerable waste material. Steel and other recyclables will be able to be removed off site and generally sold for a profit; however, other wastes will need to be disposed of in appropriate registered landfill. The volume of this material usually exceeds preliminary estimates. Opportunities may exist with local communities to reuse and recycle some of these materials and, if this is appropriate, a disposal plan will need to be developed. This will ensure the material is removed from the mine safely and distributed equitably among community groups.

### **4.3.5 Developing a human resources plan**

Critical to the success of mine closure will be the management of staff and employees. As the mine approaches closure, there will usually be a staged release of employees. Managers need to identify employees who want to leave as soon as possible and those who are prepared to stay on until final closure. It is critical to establish the skills that need to be retained in order to complete the tasks required. The key people that need to be retained are those with the necessary competencies and who can embrace change, as every day will present a different working environment. Not everyone enjoys the closure process, so retaining competent staff is critical. Suitable incentives may need to be negotiated to retain appropriate personnel.

Employees and supervisors with a sound safety philosophy are essential for a successful mine closure. Every day there will be new risks and hazards that need to be identified. Analyses of job safety need to be completed and working procedures developed and implemented to ensure tasks are completed safely.

### **4.3.6 Close the mine and implement the plans**

The quality of mine closure planning will become apparent once the last tonne of ore is passed through the crusher and it is turned off. At this stage the key people on site will be the closure manager and the closure team, including the planner who created the master plan, sequencing all of the activities, tasks and resources required. The key for a successful implementation is to follow the plan. By continually reviewing the plan, and rescheduling activities and resources, the deadlines can be met and, more importantly, costs controlled. This will ensure the closure tasks can be completed on time and within budget. At most sites, all infrastructure and plant will be removed, the site recontoured and revegetated, with a small team remaining to carry out ongoing environmental monitoring and maintenance programs.

## Case study: Mt McClure gold project, Western Australia

This case study highlights the importance of the good planning, team building and the cooperative partnerships that were created by the Newmont-Mt McClure management team to create a high-quality closure process, ultimately recognised with the Golden Gecko Award for Environmental Excellence in 2004.

Located in the Northern Goldfields, 80 kilometres north-east of Leinster, Western Australia, the Mt McClure project had several owners before it came under the control of Newmont in 2002. The mining operations consisted of a standard carbon-in-leach processing plant with multiple pits and two tailings storage facilities.

In planning for the full decommissioning of the project, a risk assessment was undertaken by the closure management team with external consultants to focus on key issues and form the basis of the closure plan. This was followed by a stakeholder consultation process to further develop the plan and the creation of a process map that outlined in detail the planning steps and sequences.

A significant innovation was the benchmarking tours. These tours, which comprised personnel of the closure team, including bulldozer drivers, earthworks contractors and consultants involved visiting numerous closed and abandoned mines within a 500 kilometre radius of the operation. The visits provided invaluable information in the design of the optimal closure plan.

Addressing the 'people' issues related to mine closure can involve a surprising number of different groups. Successful mine closure can only occur when all these people have been effectively engaged and given the ability to participate in the closure process. This was a prime aspect of the success of the Mt McClure program.

Newmont identified that closure process relationships fall into a number of broad categories, and determined to consult with all stakeholders during the closure. In the case of Mt McClure, this included:

- Indigenous people
- post-closure land users
- regulators
- industry peers
- contractor selection and management
- consultants
- universities
- owners (corporate entity)
- operational level personnel
- members of the wider closure project team dealing with human resource issues, safety, and care and maintenance management.

Effective mine closure cannot occur without broad engagement and participation across a range of organisations, communities, disciplines and aspects of society. This is a longer and more complex process but, ultimately, it will generate a much more robust outcome aligned with the project's specific conditions. Facilitating this engagement requires good leadership. The mining industry must invest in quality people who can establish quality relationships with all relevant stakeholders well before closure takes place. It can be costly, but the returns are high.

Newmont engaged and worked closely with leading consultants, researchers and contractors in earthmoving, plant demolition, tailings closure design, land rehabilitation, environmental monitoring and feral animal control to achieve 'a closure with pride' to close Mt McClure.

Further details of this case study are available in Lacy and Haymont (2005).



**Mt McClure mine site**



## 5.0 MINE COMPLETION AND RELINQUISHMENT

Mine completion and relinquishment is the final stage of a mine life. Mining lease relinquishment can only happen when the economically mineable resource has been exhausted and successful mine closure has been achieved. The aim should be to ensure the site does not leave long-term environmental or social liabilities and ultimately enables the operator to relinquish responsibility for the site's management.

Completion is the stage when a company is absolved of all further responsibility for the site. Furthermore, mining companies should be able to demonstrate:

- replacement of the mineral resource asset with sustainable benefits to the community
- attainment of completion criteria to stakeholders' satisfaction, including government.

### 5.1 Mining lease relinquishment

At some point after mine closure, successful rehabilitation and implementation of the plans, the mine operator will be in a position to relinquish the mining lease to the issuing authority. Each Australian state or territory has gazetted its own legislation and processes, and these should be reviewed and followed. There is often a need to gain a whole-of-government approach to sign off as there is unlikely to be a single authority with overall responsibility for close-out.

The process will normally involve a final evaluation of the site to ensure it has met all the designated performance and outcome criteria. This may involve a third party assessor or a panel of experts/stakeholders who can undertake the final review and provide a recommendation to the regulatory authorities. It is also an opportunity for the community closure committee (or equivalent group) to be actively involved and provide advice on whether the company has met all the community closure concerns raised throughout the duration of the project.

The following steps can be used as guide when developing a sign-off process with regulators and stakeholders.

**Table 3: Mining lease relinquishment process**

#### **1. Establishment of formal closure, sign-off and relinquishment mechanisms**

The mine operator should establish working arrangements with the lead regulatory agency that will outline the responsibilities and accountabilities, and proposed methodologies required to achieve successful sign-off. The arrangements can include:

- a closure sign-off plan, which includes a financial provision



- agreed performance criteria addressing environment, social and economic outcomes
- monitoring and reporting requirements
- self-assessment against the performance criteria as a precursor for the operator presenting close-out areas for handover
- a process for dealing with areas that fail to meet performance criteria, including corrective action
- an agreed record keeping process for sites is proposed for close-out
- establishment of a formal close-out audit process with the regulatory agency or a third party for the handover areas as part of this process.

## **2. Peer review of formal mechanisms prior to stakeholder assessment and approval**

- The use of peer review of the performance criteria, closure process and handover mechanism may provide validation of the proposed process adopted by the operator.

## **3. Sites that have successfully met the criteria are presented for relinquishing in a formal sign-off**

- the operator should consider developing a proforma/checklist in consultation with stakeholders that is applicable to each rehabilitated area presented for sign-off
- the proforma/checklist would be a record of the status of the rehabilitated area against performance criteria and any other agreements made between parties related to the area in question
- the proforma/checklist would require the signature of both parties to formalise the sign-off.

## **4. Acknowledgement from the relevant authority of areas that have been signed off as closed out**

- the operator may require a letter from the relevant minister that details those areas that have been signed off and the lease relinquished
- the letter should advise the operator that the relevant state or territory government has accepted responsibility for the rehabilitated leases.

## **5. A process is established to deal with those sites that do not meet the performance criteria**

- areas that do not meet performance criteria would be identified in an agreement with the regulatory agency and a corrective action plan developed to achieve the necessary performance criteria
- the plan will detail remedial works required to address the concern of the regulatory agency.

## **6. Establishment of a financial instrument to provide for the ongoing maintenance of the rehabilitated areas**

- the operator should consider the establishment of trust fund or other financial arrangement that would generate income for the ongoing management of rehabilitated areas, if this mechanism provides a means for early sign-off and hand over to government (Section 5.2).

## **5.2 Post-closure management requirements**

After mine closure and lease relinquishment, some rehabilitated mined land may require ongoing management and monitoring. In order to receive sign-off by regulators and stakeholders, these issues will need to be discussed with the regulators and workable solutions to post-closure management and monitoring issues finalised.

Responsibility for management following mine closure and lease relinquishment will depend on what is required, who owns the land and is responsible for managing it, and any legal aspects.

Typically, post-relinquishment management that may be required can include:

- noxious weed control
- exclusion or control of grazing animals
- control of public access
- fire management
- maintenance of safety signs and fences.

The mechanism for funding any post-relinquishment management and monitoring that may be required will need to be determined by the lease holders, the regulatory authorities and stakeholders. One method that has been suggested is to establish a trust fund and use the interest generated from the fund. Whatever agreement is reached, it is important that, when implemented, mines are absolved of any ongoing financial liability and there is no long-term financial burden on government or society. For example, in Queensland, the Environmental Protection Agency (EPA) has drafted regulations requiring companies to undertake a post-closure risk assessment to identify potential post-closure hazards and risks. An option is for lease holders to propose a post-closure bond. These bonds would be held and funds drawn down to remediate potential areas of failure (Queensland EPA, May 2006).



## 6.0 CONCLUSION

In order to meet the mining industry's principles of sustainability and to maintain its right to access resources for the benefit of all, the industry needs to ensure comprehensive mine closure is maintained within the broader context of the issues of social/economic equality and sustainable development. This recognition of a broader context of mine closure has greatly expanded the scope of what is required of industry and regulators.

Planned mine closure and completion is still at an early stage of development in Australia and there are only a few examples of mine closure planning being applied from conception through to the end of the mine life. This is largely due to the timeframe of most mining operations and the relatively recent development of integrated mine closure planning.

The mining industry, indeed any industry group, is often judged by the public on the basis of its worst performers. This handbook showcases some of the excellent work undertaken by the mining industry and minerals sector in applying the principles of leading practice mine closure and completion.

This handbook has also outlined that the following essential elements are required to achieve mine closure and completion in the context of sustainable development:

- recognising and addressing the issues that a mining operation needs to consider in its planning for closure and completion
- the development of a risk management approach to mine closure planning that applies from mine concept to post closure and integrated with whole-of-mine-life planning
- the closure activities associated with each step in the mine life cycle including establishment of a progressive rehabilitation system
- the processes and tools that can assist a mining operation achieve good practice in mine closure and completion
- the need for engagement with communities and regulators in establishing and implementing closure outcomes and practice.

The handbook has also introduced the concept of 'mine completion' as the goal of mine closure. Assigned a high priority by all levels of management, the integration of the elements outlined in this handbook with day-to-day operations management will allow a mine to reach a state where mining lease ownership can be relinquished and responsibility accepted by the next land user. To achieve this in an environment of increasing regulatory and stakeholder expectations will require superior outcomes developed and implemented in consultation with local stakeholders. Not only will the implementation of this concept of mine completion result in a more satisfactory social and environmental outcome, but it can also reduce the financial burden of mine closure and rehabilitation.

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- Department of Industry, Tourism and Resources, [www.industry.gov.au](http://www.industry.gov.au)
- Leading Practice Sustainable Development Program, [www.industry.gov.au/sdmining](http://www.industry.gov.au/sdmining)
- Ministerial Council on Mineral and Petroleum Resources, [www.industry.gov.au/resources/mcmp](http://www.industry.gov.au/resources/mcmp)
- Minerals Council of Australia, [www.minerals.org.au](http://www.minerals.org.au)
- Enduring Value, [www.minerals.org.au/enduringvalue](http://www.minerals.org.au/enduringvalue)

## **GLOSSARY OF TERMS**

### **Abandoned site**

An area formerly used for mining or mineral processing, where closure is incomplete and for which the title holder still exists.

### **Acid-based accounting**

An analytical technique that determines the maximum potential acidity that can be generated by oxidation of sulphides compared with the neutralisation potential of rock or tailings. It is also used to predict the potential of the material to be acid-producing, neutral or alkali-producing.

### **Adaptive management**

A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. The ICMM Good Practice Guidance on Mining and Biodiversity refers to adaptive management as 'do-monitor-evaluate-revise'.

### **Basal layer**

The soil or rock foundation layer at the base of an engineered structure.

### **Care and maintenance** (temporary closure)

Phase following temporary cessation of operations when infrastructure remains intact and the site continues to be managed.

### **Closure**

A whole of mine life process which typically culminates in tenement relinquishment. It includes decommissioning and rehabilitation.

### **Completion criteria**

An agreed standard or level of performance which demonstrates successful closure of a site.

### **Contaminated site**

A site at which hazardous substances occur at concentrations above background levels and where assessment shows it poses, or is likely to pose, an immediate or long-term hazard to human health or the environment.

### **Decommissioning**

The process that begins near, or at, the cessation of mineral production and ends with removal of all unwanted infrastructure and services.

### **Deterministic Estimates**

Estimates of value (cost or benefit) of the outcome of an event occurring - expressed as a single mean or mode value or a range of single values (e.g. minimum, maximum, best).

### **Environmental indicator**

A parameter (or a value derived from a parameter) which provides information about an environmental phenomenon

### **Exploration**

The search for mineral deposits up to discovery and includes the delineation of the deposit by means of drilling and sampling.

**Inactive site**

A mining or mineral processing area which is currently not being operated but which is still held under some form of title. Frequently such sites are referred to as being under 'care and maintenance'.

**Interested party**

A person, group or organisation with an interest in the process of, or outcome of, mine closure.

**Landholder**

The owner of freehold land, the holder of leasehold land, or any person or body who occupies or has accrued rights in freehold or leasehold land.

**Mining activity**

Activity whose purpose is the extraction, concentration and/or smelting of economic minerals from a mineral deposit. It includes exploration, development of mineral deposits, construction of the mine and mining (extracting and processing the ore) and closure.

**Orphan site**

An abandoned mine for which a responsible party no longer exists or can be located.

**Post-mining land use**

Term used to describe a land use which occurs after the cessation of mining operations.

**Probability costing**

Estimates of value (cost or benefit) that account for the likelihood of occurrence and the range of values of the outcome - values are expressed through a statistical analysis (e.g. Monte Carlo simulation) using a statistical distribution over the range of possible values accounting for the probability and timing of the event occurring.

**Provision**

A financial accrual based on a cost estimate of the closure activities.

**Reclamation**

Treatment of previously degraded and often contaminated land to achieve a useful purpose (concept of a time lag between degradation and reclamation, compare rehabilitation, which has an inferred continuity).

**Rehabilitation**

The return of disturbed land to a stable, productive and self-sustaining condition after taking into account beneficial uses of the site and surrounding land.

**Relinquishment**

Formal approval by the relevant regulating authority indicating that the completion criteria for the mine have been met to the satisfaction of the authority.

**Remediation**

To clean-up or mitigate contaminated soil or water.

**Responsible authority**

Any government body empowered to approve activities associated with the closure process.



**Security**

A financial instrument lodged with the responsible authority which is adequate to cover the estimated cost of closure.

**Social licence to operate**

The social licence is the recognition and acceptance of a company's contribution to the community in which it operates, moving beyond meeting basic legal requirements, towards developing and maintaining the constructive relationships with stakeholders necessary for business to be sustainable. Overall it comes from striving for relationships based on honesty and mutual respect.

**Stakeholder**

A person, group or organisation with the potential to affect or be affected by the process of, or outcome of, mine closure.

**Temporary closure (care and maintenance)**

Phase following temporary cessation of operations when infrastructure remains intact and the site continues to be managed.

**Tenement**

Some form of legal instrument providing access to land for the purposes of mining.

## APPENDIX A: Issues, consequences and options for reducing impacts

### Underground voids and shafts

Issues and consequences	Options and techniques
<b>Stope failure or void collapse</b> <ul style="list-style-type: none"> <li>• Surface subsidence</li> </ul>	<ul style="list-style-type: none"> <li>• Backfill upper levels with waste rock or paste (during operation)</li> </ul>
<b>Planned surface subsidence</b> <ul style="list-style-type: none"> <li>• Surface water impacts</li> </ul>	<ul style="list-style-type: none"> <li>• Integrate subsided landform</li> <li>• River diversion</li> </ul>
<b>Acid rock drainage and hydrocarbon pollution</b> <ul style="list-style-type: none"> <li>• Adverse groundwater quality</li> </ul>	<ul style="list-style-type: none"> <li>• Recover water table (flooding of underground)</li> <li>• treat and replace acidic water, sulphide-reducing bacteria</li> <li>• Segregate known aquifers (operational)</li> <li>• Cement and seal adits</li> </ul>
<b>Public safety</b> <ul style="list-style-type: none"> <li>• Human injury or death</li> </ul>	<ul style="list-style-type: none"> <li>• Prevent access into underground workings by backfilling decline to portal then place engineered cement cap (plug) over portal and all surface entrances (such as escape ways, vent rises)</li> </ul>
<b>Fauna</b> <ul style="list-style-type: none"> <li>• Injury or death</li> <li>• Loss of habitat</li> </ul>	<ul style="list-style-type: none"> <li>• Fauna survey</li> <li>• Creation of habitat (bats)</li> <li>• Prevent access (see above)</li> </ul>
<b>Post-mining land uses</b>	<ul style="list-style-type: none"> <li>• Stakeholder engagement to identify community preferences</li> <li>• Research</li> <li>• Tourism</li> <li>• Waste disposal</li> <li>• Bio-reactors (methane production)</li> <li>• Water supply.</li> </ul>

## Open-pit pits

Issues and consequences	Options and techniques
<p><b>Acid rock drainage and leachate production from exposed walls</b></p> <ul style="list-style-type: none"> <li>Poor groundwater quality</li> </ul>	<ul style="list-style-type: none"> <li>Backfill above predicted recovered groundwater level</li> <li>Maintain water quality during mining</li> <li>Treat water (lime)</li> <li>Seal potential ARD-generating surfaces</li> <li>Refill pit with water (such as stream diversion and/or groundwater recovery)</li> </ul>
<p><b>Void stability</b></p> <ul style="list-style-type: none"> <li>Slumping</li> <li>Wall failures</li> </ul>	<ul style="list-style-type: none"> <li>Bench highwall and reshape low wall to a stable slope angle</li> <li>Batter or blast high wall to safe and stable angle</li> <li>Backfill to support internal walls</li> </ul>
<p><b>Public and fauna safety</b></p> <ul style="list-style-type: none"> <li>Injury or death</li> </ul>	<ul style="list-style-type: none"> <li>Hostile materials may need immediate covering (such as possible spontaneous combustion)</li> <li>Barrier to discourage human access</li> <li>Abandonment bunds of competent rock (where possible) and located outside of area of wall instability</li> <li>Fencing and signage</li> </ul>
<p><b>Aesthetics</b></p> <ul style="list-style-type: none"> <li>High visual impact</li> <li>Industry reputation</li> <li>Negative public reaction</li> </ul>	<ul style="list-style-type: none"> <li>Stakeholder engagement to identify community view</li> <li>Revegetate void surroundings</li> <li>Screening</li> <li>Create wetlands</li> <li>Backfill or collapse and revegetate berms</li> </ul>
<p><b>Post-mining land use</b></p>	<ul style="list-style-type: none"> <li>Stakeholder engagement to determine possible uses</li> <li>Aquaculture</li> <li>Recreational facilities</li> <li>Educational areas</li> <li>Water storage</li> <li>Domestic and/or hazardous waste disposal</li> </ul>
<p><b>Long-term viability of rehabilitation</b></p>	<ul style="list-style-type: none"> <li>If infilled—weed control and revegetation.</li> </ul>

## Tailings storage facilities

Issues and consequences	Options and techniques
<p><b>Erosion and structural instability</b></p> <ul style="list-style-type: none"> <li>• Overtopping from floodwaters</li> <li>• High phreatic surfaces</li> <li>• Piping of materials during seepage</li> <li>• Sedimentation</li> <li>• Surface flooding erosion of batters</li> </ul>	<ul style="list-style-type: none"> <li>• Geotechnical review/risk assessment on closure</li> <li>• Integrity from construction phase</li> <li>• High quality operational management</li> <li>• Rock armouring</li> <li>• Buttrressing</li> <li>• Drainage control</li> <li>• Erosion resistant cover</li> <li>• Integration of cover into surrounding environment</li> </ul>
<p><b>Acid rock drainage</b></p> <ul style="list-style-type: none"> <li>• Internal and external instability</li> <li>• Water impacts</li> <li>• Acid soil</li> <li>• Toxic to biotic systems</li> <li>• Gas and thermal emissions</li> <li>• Cover deterioration and failure</li> </ul>	<ul style="list-style-type: none"> <li>• Geochemical characterisation and selective discharge</li> <li>• Cover and capping research studies and design to reduce water and oxygen reactions</li> <li>• Identification of cover material source and availability</li> <li>• Monitoring of cover performance and integrity</li> <li>• Store and release cover systems</li> <li>• Use as waste backfill in open pits or underground</li> <li>• Neutralisation (lime) and treatment (sulphide-reducing bacteria)</li> <li>• Segregation/isolation/encapsulation</li> <li>• Passive leachate management and treatment</li> </ul>
<p><b>Dust</b></p> <ul style="list-style-type: none"> <li>• Visual impact</li> <li>• Offsite pollution effects</li> <li>• Flora and fauna</li> </ul>	<ul style="list-style-type: none"> <li>• Surface capping to prevent wind erosion (such as rough cover, rock mulching)</li> <li>• Wet cover/wetlands</li> <li>• Revegetation</li> <li>• Wind breaks</li> <li>• Hydromulch</li> <li>• Stakeholder engagement to inform of plans to address issues</li> </ul>
<p><b>Groundwater</b></p> <ul style="list-style-type: none"> <li>• Aquifer contamination</li> <li>• Limitation of beneficial use</li> <li>• Recharge impact</li> <li>• Localised mounding</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce hydraulic head by water shedding</li> <li>• Integrate capture release systems</li> <li>• Utilise evapotranspiration</li> <li>• Cap and cover with capillary break</li> <li>• Drainage diversions</li> <li>• Neutralisation and detoxification of tails seepage</li> <li>• Wetland filtration</li> </ul>

<b>Aesthetics</b> <ul style="list-style-type: none"> <li>• High visual impact</li> <li>• Industry reputation</li> <li>• Negative public reaction</li> </ul>	<ul style="list-style-type: none"> <li>• Effective landform and cover design</li> <li>• Revegetate surface</li> </ul>
<b>Public and fauna safety</b> <ul style="list-style-type: none"> <li>• Injury or death</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholder engagement to inform development of action plans to address public concerns</li> <li>• Effective landform and cover design</li> <li>• Restrict access</li> </ul>
<b>Long-term viability of rehabilitation</b>	<ul style="list-style-type: none"> <li>• Stock and feral animal control</li> <li>• Monitoring</li> <li>• Weed control.</li> </ul>

## Waste rock landforms

Issues and consequences	Options and techniques
<b>Erosion/instability</b> <ul style="list-style-type: none"> <li>• Safety</li> <li>• Sedimentation</li> <li>• Slope/piping failure</li> </ul>	<ul style="list-style-type: none"> <li>• Signage and isolation bunding</li> <li>• Revegetation/rehabilitation</li> <li>• Landform design appropriate to materials used</li> <li>• Surface water management (stream diversion)</li> </ul>
<b>Surface Water</b> <ul style="list-style-type: none"> <li>• Sediment loading</li> <li>• Contaminated water</li> <li>• Visual impacts</li> <li>• Interruption of water courses</li> </ul>	<ul style="list-style-type: none"> <li>• Placement of erosion control measures</li> <li>• Drainage control</li> <li>• Erosion resistant outer covers</li> <li>• Material characterisation</li> <li>• Wetland filters</li> <li>• Containment</li> <li>• Revegetation</li> </ul>
<b>Groundwater</b> <ul style="list-style-type: none"> <li>• Aquifer contamination</li> <li>• Limitation of beneficial use</li> <li>• Recharge impact</li> <li>• Localised mounding</li> </ul>	<ul style="list-style-type: none"> <li>• Waste characterisation including geochemistry</li> <li>• Selective placement of covers and caps</li> <li>• Location relative to landform and substrate</li> <li>• Hydrogeology studies prior to placement</li> </ul>
<b>Acid rock drainage</b> <ul style="list-style-type: none"> <li>• Internal and external instability</li> <li>• Water impacts</li> <li>• Acid soil</li> <li>• Toxic to biotic systems</li> <li>• Gas and thermal emissions</li> <li>• Cover deterioration and failure</li> </ul>	<ul style="list-style-type: none"> <li>• Geochemical characterisation and waste selection placement</li> <li>• Cover and capping research studies and design to reduce water and oxygen reactions</li> <li>• Identification of cover material sources and availability</li> <li>• Monitoring of cover performance and integrity</li> </ul>

	<ul style="list-style-type: none"> <li>• Store and release cover systems</li> <li>• Use as waste backfill in open pits or underground</li> <li>• Neutralisation (lime) and treatment (sulphide-reducing bacteria)</li> <li>• Segregation/isolation/encapsulation</li> <li>• Passive leachate management and treatment</li> </ul>
<b>Dust</b> <ul style="list-style-type: none"> <li>• Visual impact</li> <li>• Offsite pollution effects</li> <li>• Flora and fauna</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholder engagement to inform of plans to address issues</li> <li>• Surface capping to prevent wind erosion (such as rough cover, rock mulching)</li> <li>• Wet cover/wetlands</li> <li>• Revegetation</li> <li>• Wind breaks</li> <li>• Hydromulch</li> </ul>
<b>Aesthetics</b> <ul style="list-style-type: none"> <li>• High visual impact</li> <li>• Industry reputation</li> <li>• Negative public reaction</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholder engagement to inform development of action plans to address public concerns</li> <li>• Effective landform and cover design</li> <li>• Modelled to complement surrounding landforms</li> <li>• Revegetated</li> </ul>
<b>Post-mining land use</b> <ul style="list-style-type: none"> <li>• Loss of economic benefit</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholder engagement to determine uses</li> <li>• Tourism</li> <li>• Farming/horticulture</li> <li>• Recreation</li> <li>• Stored resource.</li> </ul>

## Treatment plant, office buildings and maintenance facilities

Issues and consequences	Options and techniques
<b>Salt, heavy metals and hydrocarbons</b> <ul style="list-style-type: none"> <li>Contaminated soil</li> <li>Contaminated water</li> </ul>	<ul style="list-style-type: none"> <li>Removal</li> <li>Bioremediation</li> <li>Treatment</li> <li>Isolation and encapsulation</li> </ul>
<b>Buildings/infrastructure</b> <ul style="list-style-type: none"> <li>Safety</li> <li>Pollution</li> </ul>	<ul style="list-style-type: none"> <li>Stakeholder benefits</li> <li>Asset register</li> <li>Community or tourist facility</li> <li>Re-sell</li> </ul>
<b>Services</b>	<ul style="list-style-type: none"> <li>Recycling</li> <li>Asset register</li> </ul>
<b>Concrete</b> <ul style="list-style-type: none"> <li>Soil pollution</li> </ul>	<ul style="list-style-type: none"> <li>Removal/bury</li> <li>Recycling</li> </ul>
<b>Drainage</b> <ul style="list-style-type: none"> <li>Contaminated runoff</li> </ul>	<ul style="list-style-type: none"> <li>Reinstate/modification, divert</li> <li>Sediment traps</li> </ul>
<b>Pre/post-mining heritage</b>	<ul style="list-style-type: none"> <li>Stakeholder engagement</li> <li>Tourism</li> </ul>
<b>Compaction</b> <ul style="list-style-type: none"> <li>Restricted revegetation</li> </ul>	<ul style="list-style-type: none"> <li>Deep ripping.</li> </ul>

## Mine townships

Issues and consequences	Options and techniques
<b>Social dislocation</b> <ul style="list-style-type: none"> <li>Unemployment</li> </ul>	<ul style="list-style-type: none"> <li>Stakeholder engagement</li> <li>Counselling/retraining/placement</li> <li>Relocation</li> </ul>
<b>Regional economic loss</b> <ul style="list-style-type: none"> <li>Small business collapse</li> </ul>	<ul style="list-style-type: none"> <li>Seed capital for alternative new industry</li> <li>Long-term stakeholder involvement</li> <li>Provide sustainable industry</li> </ul>
<b>Social services</b>	<ul style="list-style-type: none"> <li>Stakeholder engagement</li> <li>Support alternative options</li> </ul>
<b>Townsite infrastructure/buildings</b>	<ul style="list-style-type: none"> <li>Stakeholder engagement to inform closure planning</li> <li>Sale</li> <li>Removal</li> <li>Asset transfer.</li> </ul>

## Water storage dams

Issues and consequences	Options and techniques
<b>Altered ecosystems</b> <ul style="list-style-type: none"> <li>• Catchment impact</li> <li>• Flora and fauna impact</li> </ul>	<ul style="list-style-type: none"> <li>• Fence</li> <li>• Breach wall</li> <li>• Rehabilitate</li> <li>• Restore natural drainage</li> </ul>
<b>Process water dams</b> <ul style="list-style-type: none"> <li>• Contaminated water/soil</li> </ul>	<ul style="list-style-type: none"> <li>• Remove water and dredge through plant (operational)</li> <li>• Rehabilitate</li> </ul>
<b>Siltation</b>	<ul style="list-style-type: none"> <li>• Draining system</li> </ul>
<b>Downstream shadow</b> <ul style="list-style-type: none"> <li>• Vegetation loss</li> <li>• Soil degradation</li> </ul>	<ul style="list-style-type: none"> <li>• Draining system</li> </ul>
<b>Long-term stability</b> <ul style="list-style-type: none"> <li>• Wall failure</li> </ul>	<ul style="list-style-type: none"> <li>• Geotechnical review and risk assessment</li> </ul>
<b>Water quality</b> <ul style="list-style-type: none"> <li>• Salinity</li> <li>• Nutrients</li> </ul>	<ul style="list-style-type: none"> <li>• Through flow system</li> <li>• Catchment management</li> </ul>
<b>Safety</b> <ul style="list-style-type: none"> <li>• Injury or death</li> </ul>	<ul style="list-style-type: none"> <li>• Restrict access (fencing)</li> </ul>
<b>Post-mining land use</b>	<ul style="list-style-type: none"> <li>• Recreation</li> <li>• Pastoral</li> <li>• Water supply</li> <li>• Asset transfer</li> <li>• Other stakeholder-defined use.</li> </ul>



## Service infrastructure

Issues and consequences	Options and techniques
<p><b>Above-ground services (such as powerlines, roads, railways, airstrips, borefields, ports)</b></p> <ul style="list-style-type: none"> <li>• Soil contamination</li> <li>• Drainage obstruction</li> <li>• Vegetation loss</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholder engagement</li> <li>• Removal of infrastructure</li> <li>• Rehabilitate</li> <li>• Reinstate drainage</li> <li>• Asset transfer</li> </ul>
<p><b>Below-ground services (such as electrical cable, piping)</b></p> <ul style="list-style-type: none"> <li>• May be exposed during rehabilitation</li> </ul>	<ul style="list-style-type: none"> <li>• Remain buried depending on depth</li> <li>• Remove and salvage</li> <li>• Rehabilitate</li> </ul>
<p><b>Vent rises/escape ways and service tunnels</b></p> <ul style="list-style-type: none"> <li>• Injury or death</li> </ul>	<ul style="list-style-type: none"> <li>• Backfill and cap with engineered concrete structure</li> <li>• Waste disposal.</li> </ul>