Australian Government

MINE CLOSURE

Leading Practice Sustainable Development Program for the Mining Industry

September 2016

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Leading Practice Sustainable Development Program for the Mining Industry.

This publication has been developed by a working group of experts, industry, and government and non-government representatives. The effort of the members of the Working Group is gratefully acknowledged.

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Cover image: Misima Mine (before and after rehabilitation), Barrick Gold Australia Ltd. Misima Island (PNG).

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CONTRIBUTOR	MEMBER	CONTACT
MWH BUILDING A BETTER WORLD	Ms Kim Bennett and Mr Harley Lacy	www.mwhglobal.com
ANGLO AMERICAN	Dr Carl Grant Global Head of Mine Closure Planning AngloAmerican	
	Corinne Unger Environmental Consultant Sustainable Mine Rehabilitation & Closure Planning	
MWH BUILDING A BETTER WORLD	Dr David Jasper, Mr Matt Braimbridge, Ms Mellissa Bolton	www.mwhglobal.com
	Mr Ron Watkins	
RioTinto	Mr Stuart Rhodes Principal Adviser - Closure & Legacy Management Health Safety Environment & Communities Rio Tinto	
Mike Slight and Associates	Mr Michael Slight	www.mikeslightandassociates.com.au

CONTRIBUTOR	MEMBER	CONTACT
URS	Donna Pershke Group Leader Sustainability	donna@pershkeconsulting.com
Northern Territory Government	Ms Tania Laurencont Principal Mining Scientist NT Department of Mines and Energy, and Mr Peter Wagget Director Mining Compliance NT Department of Mines and Energy	www.minerals.nt.gov.au
HERBERT SMITH FREEHILLS	Mr Tony van Merwyk and Mrs Fiona Sinclair	www.herbertsmithfreehills.com
	Mr Bill Biggs Principal - Environment Biggs and Associate	bill.biggs@baacs.com.au

FOREWORD

The *Leading Practice Sustainable Development Program for the Mining Industry* series of handbooks has been produced to share Australia's world-leading experience and expertise in mine management and planning. The handbooks provide practical guidance on environmental, economic and social aspects through all phases of mineral extraction, from exploration to mine construction, operation and closure.

Australia is a world leader in mining, and our national expertise has been used to ensure that these handbooks provide contemporary and useful guidance on leading practice.

Australia's Department of Industry, Innovation and Science has provided technical management and coordination for the handbooks in cooperation with private industry and state government partners. Australia's overseas aid program, managed by the Department of Foreign Affairs and Trade, has co-funded the updating of the handbooks in recognition of the central role of the mining sector in driving economic growth and reducing poverty.

Mining is a global industry, and Australian companies are active investors and explorers in nearly all mining provinces around the world. The Australian Government recognises that a better mining industry means more growth, jobs, investment and trade, and that these benefits should flow through to higher living standards for all.

A strong commitment to leading practice in sustainable development is critical for mining excellence. Applying leading practice enables companies to deliver enduring value, maintain their reputation for quality in a competitive investment climate, and ensure the strong support of host communities and governments. Understanding leading practice is also essential to manage risks and ensure that the mining industry delivers its full potential.

These handbooks are designed to provide mine operators, communities and regulators with essential information. They contain case studies to assist all sectors of the mining industry, within and beyond the requirements set by legislation.

We recommend these *leading practice* handbooks to you and hope that you will find them of practical use.

Senator the Hon Matt Canavan

Minister for Resources and Northern Australia

The Hon Julie Bishop MP

Minister for Foreign Affairs

1.0 INTRODUCTION

This revised handbook addresses mine closure, one of the themes in the Leading Practice Sustainable Development (LPSD) Program. The program aims to identify key issues affecting sustainable development in the mining industry and provide information and case studies that illustrate a sustainable basis for the industry. A number of other themed handbooks in the series complement this handbook. The leading practice handbooks integrate all phases of mineral production, from exploration to post-closure and relinquishment.

The mining industry is embracing the concept that completion and relinquishment incorporate delivery of a defined post-mining land use rather than just closure when the operational stage of a mine ceases and decommissioning is complete. To assist in planning for this, a new phase in the life of mine (LoM), termed 'post-closure management' (Section 3.7) has been added to this handbook to accommodate longer term considerations for companies to manage post-decommissioning conditions en route to relinquishment.

The concept of 'leading practice' exemplifies excellent approaches to mine closure. 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.

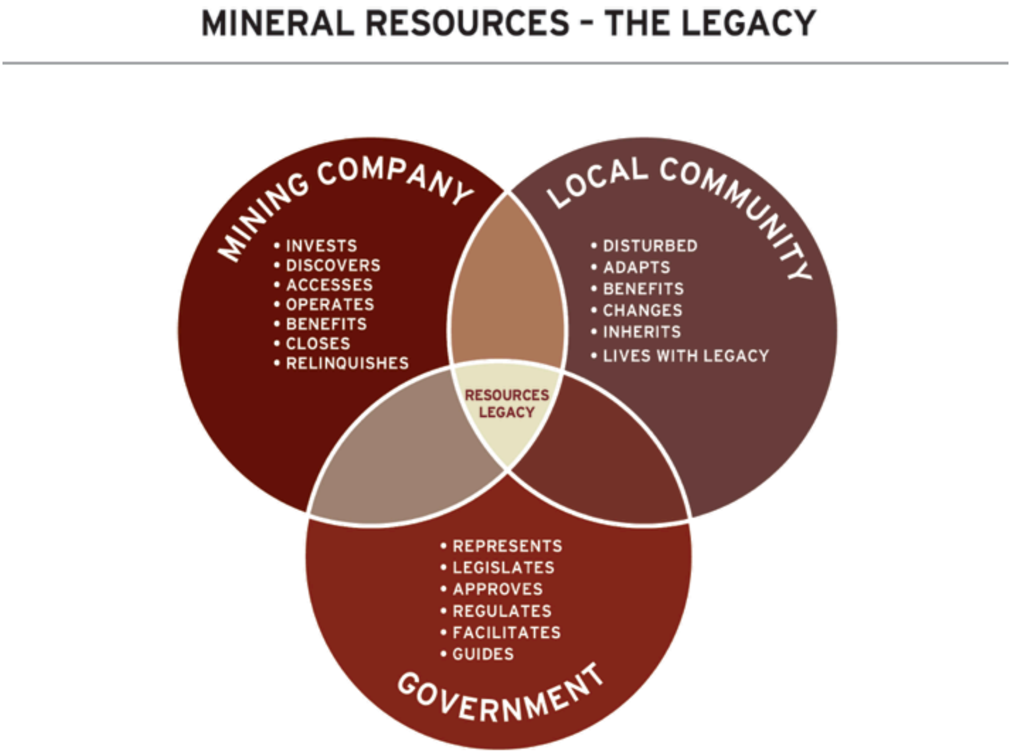
The future of the mining industry is dependent on the legacy it leaves. Industry reputation is affected when mines are abandoned or long-term detrimental environmental impacts emerge because they were not appropriately addressed during the LoM. The industry today recognises that to gain access to future resources it needs to demonstrate that it can effectively manage and close mines with the support of the communities in which it operates. Ongoing engagement with the community throughout the LoM makes good business sense for companies as they seek to contribute to the building of sustainable regional communities through long-term partnerships.

The word 'legacy' is used many times in this mine closure handbook and is a critical term. The word is generally used with a negative connotation by the industry and its detractors, but in reality legacy is defined as and implies 'a gift handed down'. However, it is acknowledged that a legacy can be either positive or negative, depending on your point of view.

The mineral resource legacy (Figure 1) illustrates the prime relationships in the discovery and utilisation of minerals between mining companies, local communities and government and lists and describes some of the broad effects as verbs. The common interface of these three primary stakeholders is the resources legacy.

Social equity and a new way of looking at the resources legacy are needed now, as conflict over humankind's search for minerals and use of minerals, and the resource input necessary to extract and process resources, have a massive global effect. However, mining is a vital primary industry concerned with obtaining or providing natural raw materials for conversion into commodities and products for the consumer. In economic terms, it is those primary industries that decide our economic success. The economic gift of the resource legacy brings responsibility for all parties and is therefore broadly discussed in this handbook.

Figure 1: The mineral resource legacy



Source: Lacy and Bennett (2015).

The legacy framework in Figure 1 provides a visual context for approaching the broader discussion of the nature of the mineral resource legacy in the interests of fostering understanding of continuing LoM cycles among company employees, local communities, regional stakeholders, shareholders, company managers, non-government organisations (NGOs) and society as a whole.

Mine closure is a process. To be successful, it should commence with early planning, involve progressive rehabilitation during operations, and culminate with final decommissioning, rehabilitation and relinquishment. 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 closure and rehabilitation ultimately determine the nature of the legacy left behind as a post-closure land use for future generations. If they are not done in a planned and effective manner, throughout the LoM, a site may continue to be hazardous and a source of pollution for many years to come. The overall objective of mine relinquishment 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.

The LPSD Program has developed an internationally successful series of 17 handbooks that cover leading practice in mining management. Each handbook is made available for public download in English, and a selection of handbooks is translated into other languages according to international demand (http://www.industry.gov.au/resource/Programs/LPSD/Pages/LPSDhandbooks.aspx).

In addition to this handbook, the series includes: *A guide to leading practice sustainable development in mining; Airborne contaminants, noise and vibration; Biodiversity management; Community engagement and development; Cyanide management; Evaluating performance: monitoring and auditing; Hazardous materials management; Mine rehabilitation; Preventing acid and metalliferous drainage; Risk management; Tailings management; Water stewardship; Working with Indigenous communities; Community Health and Safety and Energy management in mining.*

The target audience

Mine management

This handbook is primarily intended for use as a management tool to improve closure planning and execution on mine sites. The target audience includes people in a variety of roles in and around the industry, although the main focus is onsite mine managers, who are the pivotal decision-makers to drive leading practice at mining operations. It is the responsibility of the mine manager and their team to assess risk, identify opportunities and take action to enhance the value of the operation. Managers are also in a position to use this experience to formulate a business case to change corporate standards and practices. Implementing thorough and effective progressive rehabilitation, closure planning and execution will add value to the mining operation.

The term 'mine management' is used generically here, and aims to capture those with management responsibilities in functional areas such as exploration, construction, maintenance, metallurgy, mining and environmental and community liaison. The layout of this guide allows these specialists to extract information of most value to them in their day-to-day or strategic roles.

Technically oriented audience

Those in non-operational roles, but with an interest in leading practice in the mining industry, will find this handbook relevant, including company directors, managers, community relations practitioners, consultants and suppliers to the industry, and government agencies.

Non-technical audience

The handbook is also a useful textbook on the fundamentals of closure planning for those who might not have worked in or been exposed to the industry. Although some sections are necessarily technical, it has been written to be understood by a wide range of readers, including stakeholders associated with or potentially affected by mining operations. That readership may include representatives of NGOs, mining communities, neighbouring communities and students. It has been written to encourage those people to play a critical role in continuously improving the mining industry's sustainable development performance.

Given the wide target audience for the handbook and the wide variation in mining experience of the readers, a glossary is provided at the end of the book.

2.0 SUSTAINABLE DEVELOPMENT AND CLOSURE

KEY MESSAGES

- In the minerals sector, sustainable development means that investments in minerals projects should be financially profitable, technically appropriate, environmentally sound and socially responsible.
- As access to resources becomes tied to industry and corporate reputation, effective closure processes and satisfactory mine relinquishment become critical to a company's ability to develop new projects.
- Closure planning requires the establishment of a performance framework for mine closure that facilitates a consistent approach and enables success in closure to be measured.
- Ongoing stakeholder engagement between regulators, the community and industry is an important part of efficient and effective mining operations, including resources development and managing cumulative impacts.
- Biodiversity conservation is, and will continue to be, an important consideration in mine closure planning.
- Comprehensive characterisation and management of materials (including soils and wastes) throughout the LoM is widely recognised as critical to rehabilitation, mine closure and post-mining land use.
- Risk management is an integral part of mine closure planning, and an LoM risk management approach can enable an operation to identify risks and develop controls to achieve sustainable mine closure, rehabilitation and relinquishment.
- Progressive rehabilitation is an LoM process that produces benefits that enable post-mining land-use objectives to be achieved.
- It is imperative that the stakeholders and proponent arrive at an agreed set of closure objectives and completion criteria as part of the approvals process that will allow the company to relinquish the site in a manner that meets regulatory requirements and community objectives.
- A commitment to leading practice sustainable development is a prerequisite for a mining company to attain and maintain its 'social licence to operate' in a community.

The most widely accepted definition of sustainable development was provided by the World Commission on Environment and Development in its landmark report, *Our common future* (Brundtland Report 1987): 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

In the minerals sector, sustainable development means that investments in minerals projects should be financially profitable, technically appropriate, environmentally sound and socially responsible. Businesses involved in extracting non-renewable resources are subject to mounting pressure to embed the concept of sustainability into strategic decision-making processes and operations. In addition to these considerations, responsible corporations have been able to move towards sustainability by developing a range of appropriate stewardship initiatives. Economic development, environmental impact and social responsibilities must be well managed, and productive relationships must exist between governments, industry and stakeholders.

A range of sustainable development policy frameworks developed by industry and other organisations are now acting as drivers for improved practice. One such approach is demonstrated 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). The MCA framework became a working guide for Australian mining companies as they sought to embed, and continually improve, sustainable development approaches in their strategy and operations. In 2012, the initial 10 principles were revised; the revised draft principles and elements pertaining to closure are listed in Appendix 1 of this handbook.

Ideally, mines close only when their mineral resources are exhausted, a mine closure plan is in place and the plan is 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. Predetermined outcomes can be achieved or progressed satisfactorily and there is 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, 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 that 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.

2.1 The environment and closure

The development of a mining operation, including its processing facilities and infrastructure, usually involves the permanent alteration of existing landforms, disturbance to flora, disruption of faunal habitats, hydrological impacts and potentially some level of contamination.

Impacts on the environment

- *Topography and landform:* Temporary changes to the topography from mining operations include access and haul roads, laydown and hardstand areas, topsoil stockpiles, process plant sites and support infrastructure. Permanent changes include open pit voids, waste rock landforms, tailings storage facilities (TSFs) and permanent water flow diversions.
- *Flora:* Direct impacts on floral communities occur mainly through clearing for the mine, waste rock landforms, processing plant, TSFs and associated infrastructure.
- *Fauna:* The impact of mining on fauna can generally be described as either primary or secondary. The primary impact is the direct destruction of habitats through land clearing and earthmoving. Secondary impacts relate to activities with varying degrees of disturbance beyond the immediate location where mining is taking place, such as access and haul roads; powerlines; pipeline and transport corridors; other infrastructure; introductions of feral animals or increases in their numbers; and general workforce activities.
- *Surface water hydrology and groundwater:* The development of open pits, stockpiles, waste rock landforms, TSFs, processing plant and other infrastructure often interrupts natural drainage paths. Interference with drainage patterns can result in deprivation of water to drainage systems downstream of the mining development or localised 'shadowing' effects on some vegetation that may rely on intermittent flows.
- *Soil and water contamination:* Chemical reactions in waste rock and tailings have the potential to be detrimental to the environment and rehabilitation, and to result in the contamination of surface soils, groundwater and surface water. In addition, mining and processing operations require the transport, storage and use of a range of hazardous materials, including fuels, process reagents, lubricants, detergents, explosives, solvents and paints. If these materials are not properly managed, they 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 help to minimise their impacts and the future cost of management. However, there will inevitably be residual impacts at the completion of mining and processing operations that will need to be managed:

- public safety hazards and risk
- potential sources of ongoing pollution
- future land-use and resource demands
- ecological compatibility
- community expectations
- aesthetics.

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

2.2 Context and strategy

There are many reasons why mines may close prematurely. Research shows that almost 70% 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 the exhaustion or depletion of reserves including:

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

Poorly closed and derelict (orphaned and abandoned) mines provide a difficult legacy issue for governments, communities and mineral 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 relinquishment become critical to a company's ability to develop new projects.

As the risks and opportunities associated with closure become better understood, that can affect the closure planning process to optimise long-term business strategies. The vision of a mine closure plan should be to ensure that a process is established to guide all decisions and understand the implications of decisions during the LoM.

Closure planning requires the establishment of a performance framework for mine closure that facilitates a consistent approach and enables success in closure to be measured. This handbook outlines an integrated approach to mine closure planning and provisioning for closure, and advocates that progressive rehabilitation can achieve effective financial provision and planning for mine relinquishment and ameliorate the negative effects of unexpected or unplanned closures.

Aspects of a performance framework that are covered in more detail in this handbook include:

- legal and regulatory requirements
- risk management
- environment and social management requirements
- post-mining land use
- closure objectives and completion criteria
- financial assurance and provisioning
- decommissioning requirements
- safety considerations.

The best closure strategies and plans are dynamic and under constant scrutiny. Reviews reflect both changes in the physical status of the project and the increase in knowledge and understanding of the project as it progresses through its LoM.

2.3 Legal and regulatory components

2.3.1 Commitments, compliance and regulation

Specific closure-related obligations in most Australian jurisdictions involve mine closure planning as part of the approval process. These obligations arise through key approval regimes (particularly those pursuant to environment, planning and mining-related legislation) and set a minimum industry standard for closure, which must be planned for and evidenced before approvals can be obtained. Regulators are generally provided with significant enforcement powers over these commitments, which may also link to financial securities.

The operation's specific closure-related obligations must be carefully considered to ensure an outcome is acceptable to the regulator, in addition to ensuring the best outcome for the operator and the environment. An example of this is the development of closure objectives and completion criteria, which are developed through this process and continue to apply throughout the LoM. Failure to properly plan for mine closure may result in rehabilitation and closure criteria not being met, resulting in ongoing and expensive rehabilitation work to close out key closure objectives.

Numerous general legal obligations also relate to closure. They arise under legislation, in each jurisdiction and pursuant to common law principles. General obligations may also arise through key approval regimes (particularly those pursuant to environment, planning and mining-related legislation), as well as under a range of specifically targeted legislation that generally exists to manage issues such as contamination; the protection of flora and fauna; landfills; controlled waste; dangerous goods; land management; and specific materials, such as hydrocarbons and asbestos.

These general obligations are relevant during operations, decommissioning and closure and after closure. Mines that have not been returned to sustainable ecosystems beyond their LoM have the potential to cause environmental damage both onsite and offsite as a result of the passage of contaminants through key contamination pathways (wind, surface water and groundwater). Legislation contains powerful tools that require operators to arrest and remediate such problems.

In addition to managing statutory obligations, operators must also consider the potential for common law liability. The three main common law actions that may be taken against the operator of a mine site in relation to its environmental or health and safety performance in closing a site are nuisance, negligence and breach of statutory duty. Appropriate mine closure planning and provisioning helps a company to avoid such actions arising and, if a private action of this nature is taken, it can demonstrate that reasonable precautions were taken to prevent and mitigate impacts to third parties.

It is important to identify the company's closure obligations in order to eliminate or manage legal risks and ensure that all the obligations are met. A useful approach is to categorise legal obligations according to the entity to whom the obligation attaches. Generally, closure-related obligations will fall on the holder of an approval, the occupier of the land or premises, or the person undertaking the activity. It is important to consider how the obligation is categorised to determine who bears the risk and how the obligation can be retired. Where the obligation is the responsibility of the approval holder, potential liability can be minimised by the relinquishment or expiry of the relevant authority. Where the obligation lies with the occupier, potential liability can be reduced by ceasing to occupy the premises. By contrast, liability resting with the person who undertook the impugned action cannot be easily extinguished, resulting in the potential for ongoing liabilities where good closure outcomes are not maintained.

2.3.2 Government–community: a critical 'interface' affecting closure and relinquishment

An important aspect of mining development and its sustainable land use is the part that government and regulators play in the interface between the community and the mining industry. Effective high-quality communication and well-formed respectful relationships between regulators, the community and mining representatives are an important part of efficient and effective resources development.

When mining companies conduct mine exploration, development, operations and closure in their region, communities expect the regulator to provide the surety of regulation and to represent their interests in administering the applicable laws and regulations effectively. Conversely, resource companies expect the regulator to effectively support the development of minerals resources while advising on the processes, procedures and requirements of the applicable laws and regulations.

Governments inevitably respond to community concerns, and this has resulted in changes in legislation and an increased responsibility on the part of the mining industry to perform well and reduce the risk of liability associated with the closure of mines.

Hence, governments can find that they:

- are called upon to fund the remediation of abandoned mine sites that are affecting communities and ecosystems
- respond to unforeseen and inadequate mine closures by reducing the ease with which mining conducts business, increasing the costs of doing business
- provide communities with capacity to withdraw the social licence to explore and operate.

By way of example, the Queensland Government in 2012 reviewed its operational policies related to resource extraction and impacts in an effort to improve guidance to both industry and community in:

- the *Mineral Resources Act 1989*
- the *Petroleum and Gas (Production and Safety) Act 2004*
- the *Petroleum Act 1923*
- the *Greenhouse Gas Storage Act 2009*
- the *Geothermal Energy Act 2010.*

Best practice in mine closure, using concepts in this handbook, encourages industry to responsibly apply and demonstrate to community and government that it does implement good mine closure programs. All stakeholders need to have evidence that, with systematic data gathering and investigations, we can solve challenges and collectively understand cumulative impacts.

> In the United States, a broadscale and comprehensive example of regulatory response is the Hardrock Mining and Reclamation Act of 2015 (currently referred to a Senate committee) (US Congress 2007/2009). The Act was created in response to the identification of around 500,000 hardrock mines in the USA that are not effectively covered by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA 1980). The 2015 Act provides for gathering of fees, penalties and royalties.

Approximately two-thirds of all royalty revenues to this fund are allocated towards a 'Reclamation Fund' to clean up abandoned mines on federal lands. The remaining third is allocated to a 'Locatable Minerals Community Impact Assistance Fund', which provides assistance to communities that are socially or economically affected by the boom-and-bust cycle of mining and mineral processing activities.

2.3.3 Cumulative impacts

In the 1990s and early 2000s, Australia experienced rapid development in the nation's resource regions. With such rapid expansion, a range of complex environmental and socioeconomic impacts became increasingly apparent at three levels:

- *localised cumulative impacts* resulting from mining operations in the immediate vicinity of the project site; they include cumulative effects from operations that are close enough to potentially cause additive effects on the environment or sensitive receptors
- *regional cumulative impacts,* including the project's contribution to impacts that are caused by mining operations within a region; for example, within the Bowen Basin each coalmining operation by itself might not have a substantial impact, but their cumulative effect on habitat value, water quality and regional socioeconomics may warrant consideration
- *global cumulative impacts*—greenhouse gas emissions.

Mining development has generated a range of positive cumulative impacts at the local and regional scales, such as local business development, employment and the provision of services and infrastructure. However, accompanying these benefits are potentially far-reaching impacts that are challenging traditional regulatory and management responses, including:

- increased airborne dust and pollutants
- effects on water quality from mine site discharge
- visual amenity impacts
- land-use conflict, particularly in relation to high-quality agricultural land and urban fringes
- loss of biodiversity and impacts on ecosystem services.

Each of these impacts is directly or indirectly linked to complex social or biophysical receiving environments, and each involves incremental and combined effects and complex feedback processes (Brereton et al. 2012). The cumulative impacts of mining projects and the quality and nature of the rehabilitation and closure landscape have become more important to the community, as the impacts of inadequately closed mines are viewed in a collective sense. 'Cumulative impacts are the successive, incremental and combined impacts (both positive and negative) of an activity on society, the economy and the environment' (Brereton et al. 2012).

Ensuring that the cumulative impacts of all sources are kept within acceptable limits requires consideration of the combined, secondary and interacting impacts at a system level (Duinker and Greig 2007). Collective approaches to the management of cumulative impacts, involving not just mines and companies but government, community and other industries as well, are often regarded as having the potential to produce sustainable development outcomes. Examples of collaborative initiatives include:

- *multi-sector:* across government, civil society, the private sector, or any combination of them
- *multi-industry:* multiple industries (such as mining and agriculture)

- *intra-industry:* multiple companies within an industry
- *intergovernmental:* multiple government departments, multiple levels of government, or both.

In Queensland, there is official encouragement of collaboration. The generic terms of reference for environmental impact statements, issued by the Department of Natural Resources and Mines (formerly the Department of Environment and Resource Management), say, 'Where impacts from a project will not be felt in isolation to other sources of impact, it is recommended that the proponent develop consultative arrangements with other industries in the proposal's area' (Brereton et al. 2012).

Collaboration is not always the answer, and the potential benefit will only be realised if the collaborative group has appropriate brokering, coordination and leadership, overcomes challenges and avoids potential pitfalls associated with forming and maintaining networks (Huxham 2003).

It is recognised from a regulatory perspective that policies governing rehabilitation and post-closure landscapes influence the cumulative impacts of mining and community perceptions. For example, cumulative impacts on agricultural land and other land uses are now recognised by the New South Wales (NSW) Government, which has introduced agricultural impact assessments as part of the approvals process for mining projects.

It was predicted that the Upper Hunter Valley would experience an expansion in coal mining activity over the next 20–30 years. As a result, on 20 September 2012, the Australian Government entered into an agreement with the NSW Government to undertake a strategic assessment of a biodiversity plan for coal mining in the Upper Hunter Valley under section 146 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). New mining proposals are expected to require approval under federal environmental law alongside the mining state approval processes due to the occurrence of nationally listed threatened species and ecological communities in this area. The impact assessment has been undertaken using a modified version of the Biodiversity Certification Assessment Methodology. Currently the assessment is still under consideration (NSW DPE 2016); however, in the interim an Upper Hunter offsets fund will be established to allow mining companies to pay a sum calculated to be the equivalent of their offset obligations (NSW OEH 2014). All mining companies that expect to undertake significant coal mining operations in the Upper Hunter Valley are participating in this process. These companies are funding biodiversity assessments on mining leases and preparation of the biodiversity plan which will be written by the NSW Government. Field assessment and offsetting calculations will be undertaken by independent consultants that have been accredited to use the NSW Biodiversity Certification Assessment Methodology.

Considerable conservation benefits can be gained and will include:

- comprehensive information on biodiversity values within lease boundaries well in advance of mine planning (this should allow impacts to be avoided to the fullest extent practicable)
- guidelines to mitigate impacts on listed threatened species and ecological communities during the mine construction and operation phases
- a framework for the offsetting of unavoidable impacts, including the creation of a pooled offset fund, the identification of regional priorities for investment and the promotion of innovative ways to facilitate the private supply of offsets
- a framework for the ecological restoration of lands at the completion of mining.

This information is from the Department of the Environment website: http://www.environment.gov.au/node/25244.

Before beginning operations in a given area, mining companies need to delineate the biodiversity values in that area. The resulting information is essential for the identification of key risks to biodiversity and the effective design of management programs and rehabilitation and closure objectives. The initial phase of baseline monitoring involves reviewing available background information on biodiversity values in the local, regional, national and international contexts.

In Australia, any development project is subject to national and state assessments if values of significance have been defined under the relevant legislation. There are protected areas under both federal and state legislation that may exclude mining, exploration, or both in particular areas (such as national parks or marine parks).

2.4 Local and regional biodiversity

Biodiversity describes the breadth of life on earth—from animal species to genes and ecosystems. Biodiversity conservation is, and will continue to be, an important consideration for mining in the future. This is due in part to a growing awareness of the importance of biodiversity conservation, but also because the industry often operates in remote and environmentally sensitive areas of the world. Demonstrating a commitment to biodiversity conservation is now an essential element of sustainable development for the mining and metals industry (Appendix 1, Principle 7).

Mining has the potential to affect biodiversity throughout the life cycle of a project, both directly and indirectly. Direct or primary impacts from mining can result from any activity that involves land clearance, such as access road construction, exploration drilling, overburden stripping, tailings impoundment construction and direct discharges to water bodies (riverine tailings disposal) or the air (such as dusts or smelter emissions). Direct impacts are usually readily identifiable. Indirect or secondary impacts can result from social or environmental changes induced by mining operations and are often harder to identify immediately. The potential for significant impacts is greater when mining occurs in remote, environmentally or socially sensitive areas.

A key impediment for managing biodiversity is currently limited taxonomic knowledge; it is estimated that only one in four species in Australia is known (PMSEIC 2005). For the minerals industry, this means significant uncertainty in pre-mining biodiversity assessment, particularly in biodiverse regions.

Despite the significant potential for negative impacts on biodiversity from mining operations, mining companies can do a great deal to minimise or prevent such impacts in areas identified as being appropriate for mining. They also have many opportunities to enhance biodiversity conservation in their areas of operations. Leading practice is demonstrated where companies develop tools and approaches that improve their management of biodiversity impacts. For further reading, see the *Biodiversity management* leading practice handbook (DIIS 2016a).

Good practice, collaboration and innovative thinking can advance biodiversity conservation in the industry. There is growing recognition of the critical role that business can play in piloting a range of innovative approaches to biodiversity conservation (in partnership with governments, the community and researchers) to change threats to biodiversity into opportunities. For its part, industry is looking for the continued development of biodiversity guidance documents and a structured approach that follows accepted guidelines for identifying, measuring, and managing impacts and risks.

The ICMM's *Mining and biodiversity: a collection of case studies* presents case studies on biodiversity management during the planning or project phases of mines in the US, Indonesia and Madagascar, followed by case studies of biodiversity programs implemented by operating mines in Argentina, Australia, Brazil, Colombia, Namibia, Peru and South Africa (ICMM 2010).

Mitigation and offsets
Mitigation and offsets are being increasingly considered by Australian regulators and mining companies. Mitigation generally refers to actions taken to avoid, minimise, rehabilitate or offset the effects of direct or indirect environmental damage. Environmental offsets are actions that provide environmental benefits that counterbalance the significant residual environmental impacts of a project or activity. Unlike mitigation actions, which occur onsite as part of the project and reduce the direct impact of the project, offsets are undertaken outside of the project area and counterbalance significant residual impacts. When applied, these concepts can effectively balance access to mineral resources with the protection of biodiversity values. Further development of these approaches is likely to provide increasing opportunities for the mining industry as it seeks to adopt sustainable biodiversity management practices.

The interdependence between people and biodiversity is most apparent for some indigenous peoples, who may lead a subsistence lifestyle and be critically dependent on biodiversity, or whose culture and history are intimately associated with the natural environment and ecosystems. In many Western cultures, although our dependence on biodiversity has become less tangible and apparent, it remains critically important (ICMM 2006).

For further reading, see the *Working with Indigenous communities* leading practice handbook.

Further information on potential impacts on biodiversity (and measures to reduce them) is in in Appendix 2 of this handbook.

Case study: The development of an area's human and social capital as part of a mine's operation and closure plans

Misima Gold Mine, which began operations in 1987, operated until 2004 and produced 3.6 million ounces of gold. The mine was on Misima Island, which is located 200 km east of the Papua New Guinea (PNG) mainland. Final deconstruction and rehabilitation earthworks were completed in April 2005.

The mine was operated by Misima Mines Ltd and owned through a joint venture between Placer Dome—Misima Mines' parent company (80%)—and PNG state company Orogen Minerals (20%). In 2006, Barrick acquired Placer Dome and its mines. The mining lease was formally relinquished by Barrick in December 2011 after the completion of PNG Government regulatory requirements.

Sustainability impacts
Misima Island was seen as being particularly vulnerable to the social impacts of large-scale mining, as the islanders had not been exposed to a large-scale development before and had limited experience with a cash economy. Before the mine opening, life on the island was based on subsistence farming and fishing, supplemented with cash earned from the sale of copra.

During the mine's operation, road infrastructure was upgraded in order to transport workers from their remote villages to the mine site. Misima Mines built classrooms, medical aid posts and freshwater supply systems through a tax credit scheme that redirected a percentage of the government's revenues back to the local community. Existing trade stores expanded and new ones opened to sell workers a wider range of goods. The government built a high school on the island, enabling more local children to extend their education.

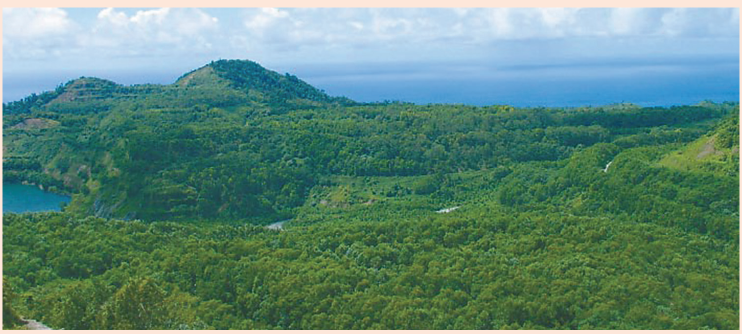
Following the mine's closure, the improvements made to the islanders' standard of living began to deteriorate. Employment opportunities were reduced, and many landowners had to return to subsistence farming and fishing. Funding for the ongoing improvement and maintenance of infrastructure systems related to the mine's operation, such as roads, electricity grids and improvements to the airport, ceased, as no other industries had been developed to provide alternative revenue streams. In addition, the PNG Government had limited capacity to maintain those projects through the national budget.

The response of mine management

Misima Mines focused on developing the island's human and social capital. The improved education infrastructure created a relatively high level of literacy on the island. The company also helped employees get certification in various skilled trades and professions, such as accountancy, nursing and engineering. The company hired an NGO to help local leaders develop the skills needed to create strategic plans for each village and then take them to higher levels of government. Misima Mines also helped the traditional landowners to get organised and initiate a trust fund with their royalty money.

Social capital meant having enough internal cohesiveness to agree upon, and work towards, common goals. On Misima, traditionally, collaborative action seldom extended beyond the clan and village levels. The challenge was to have the diverse, dispersed villages and clans come together and take charge of planning their collective future. Misima Mines convened an advisory group composed of the leaders of all the stakeholders. It included churches, a women's association, a national human development NGO, an international environmental and social NGO, the landowners and four levels of government.

The major problems that the advisory group faced were food security, alternative sources of cash income and public infrastructure maintenance. Misima Mines took a plot of land and started an agricultural research and training centre that experimented with various high-value, low-weight cash crops for export, such as vanilla, kava and nutmeg.



Rehabilitation of Misima Mine, with pit lake to the left of image.

Source: *Mine closure and completion* handbook (2006).

2.4.1 Climate change and awareness of future conditions in the area

'Climate change, whether driven by natural or human forcings, can lead to changes in the likelihood of the occurrence or strength of extreme weather and climate events such as extreme precipitation events or warm spells' (Cubasch et al. 2013). Climate science indicates risks and uncertainty associated with climate trends and extremes in the future.

The closure and relinquishment of current mines and improperly closed or abandoned mines are vulnerable to climate change, and may require climate adaption and research to ensure delivery of resilient rehabilitation in post-mining landscapes. With more than 50,000 abandoned mines in Australia (Unger et al. 2012), climate change poses additional challenges to governments left managing those sites (Mason et al. 2013). If climate adaptation measures are not integrated into short-, medium- and long-term designs for closure, many more mines will need to be managed in perpetuity.

The environmental stability of a rehabilitated and closed mine site is influenced by changes in:

- rainfall amount and intensity and evaporation rates
- temperature averages and extremes
- fire frequency and intensity
- other changes in land use beyond the mine site.

In Australia, it is likely that:

- intense rainfall in most locations will become more extreme, driven by a warmer, wetter atmosphere
- the combination of drying and increased evaporation is likely to reduce soil moisture over much of southern Australia
- an increase in fire-weather risk is likely (CSIRO–BoM 2007).

Adaptation includes 'low-regret' options in which moderate levels of investment increase the capacity to cope with future climate risks (Mason et al. 2013). Both short-term and long-term risks are associated with climate uncertainty when undertaking rehabilitation works and closure planning. In short time frames, seasonal uncertainty of rainfall and temperatures can influence success or failure in one or more seasons of rehabilitation. If rain is delayed or inadequate after seeding, then germination and establishment may fail. Conversely, if rainfall is far more intense than has been experienced in the past, prepared surfaces (ripped, topsoiled and seeded) may be washed away and drainage controls destroyed.

2.4.2 Climate change and engineering for site rehabilitation

In some cases, the slope angle of mine waste landforms or embankments that are to remain for the long term need to adapt to different climate conditions; this is particularly relevant where covers are integrated into the final landform design. Erosion modelling and a geomorphic approach to landform and drainage design are needed to define the characteristics of stable post-mining landforms in the long term. Straight lines, flat surfaces, angular landforms and trapezoidal drains may be easier for engineers to design and efficient to construct, but may be inherently unstable if the design does not integrate geomorphic principles.

The resources industry and governments are judged on their ability to mitigate and manage closure risks and adequately regulate mines, respectively, so that effective mine closure results. This need is heightened when industries and governments are faced with higher community expectations of the long-term stability of post-mining landforms and greater uncertainty in climate.

The Australian National Council on Large Dams defines the long term as 1,000 years (ANCOLD 2012). Leading practice dictates that a post-closure design life of 1,000 years be adopted as being considered 'in perpetuity'.

The importance of comprehensive characterisation and management of materials (including soils and wastes) throughout the LoM is often overlooked. The level of characterisation and management required depends on the nature of the project and site-specific environmental factors; however, these factors have been widely recognised as being critical to successful mine rehabilitation and closure and the attainment of the desired post-mining land use.

2.5 Mine waste management

Mining and onsite mineral processing do not normally alter the chemical composition of the ore and associated waste, although process residues may contain chemicals or potential contaminants. The risk of geochemical contamination arises from the reduced particle sizes created by mining and milling and the oxidising environment in which the wastes are stored. Reduced particle size enhances water–rock and atmosphere–rock interactions, increasing the rates at which chemical reactions can proceed on exposed mineral surfaces. Progressive fracturing of rocks further exposes fresh mineral surfaces on which reactions may be particularly rapid.

While the characterisation of soils and waste should start during the exploration phase and continue throughout all stages of the operation, it is essential that material characterisation is the key driver in the planning process. Injudicious handling and temporary storage of waste materials during mining can greatly affect the potential for environmental contamination, for costly re-handling of mine waste materials after closure, or for both.

Early characterisation of materials enables plans to be developed to avoid potential risks and to gain maximum benefit from material that may be particularly well-suited for the construction of site infrastructure or for use in rehabilitation. Many regolith and waste rock materials, once disturbed and brought to the surface during mining operations, behave differently when out of their natural settings. These materials often have intrinsic properties that make their management and incorporation into constructed landforms difficult.

The development of a mine waste inventory, incorporating the volumes of waste units, their characteristics and target placement within constructed waste landforms, can greatly assist the planning, construction, rehabilitation and closure of waste landforms and TSFs. Planning for the management of waste materials and their placement and appropriate landform design early in the LoM can significantly reduce the additional management and costs associated with further handling or the reworking of waste landforms towards the end of the LoM or at closure.

Mine waste management should be viewed in terms of a dynamic pollution model in which the physical character, chemical source, mode of transport and chemical sink are identified. While a degree of erosion and release of chemical substances from the stored waste are inevitable in the long term, the aim is to prevent offsite impacts and chemical pollution (that is, to ensure that the rate of chemical release does not give rise to concentrations in the environment that damage human health or the environment). To that end, it is necessary to identify those parts of the environment that are most sensitive, such as flora, fauna, surface water and groundwater.

The difficulties faced in the restoration of functioning ecosystems on such landforms, often under extreme ranges in temperature and rainfall, are often exacerbated by the properties of the waste material. The physical, chemical and geochemical characterisation of mine waste materials is used to identify potentially problematic waste—for example, potentially acid-forming, sodic or saline waste—or waste units suitable for use as near-surface growth medium, water-holding material or surface armour.

Identification of these characteristics—viewed in conjunction with local climatic conditions, the effects of climate change, the way waste materials are likely to weather and develop over time, and target closure objectives and completion criteria—is paramount to appropriate landform design.

2.6 Risk management

Risks associated with closure and post-closure phases during the LoM cover both economic and non-economic consequence types. These risks are long term. The expectations of the local community, government, landowners, neighbouring property owners and NGOs need to be taken into account. A well-planned and managed closure process will protect the community from unintended consequences well after the mining company has left the district and will protect the reputation of the company.

Risk management is an integral part of mine planning and management. A risk management system can enable an operation to identify risks and develop controls to achieve sustainable mine closure and relinquishment. One method of incorporating risk planning into closure planning is to develop a risk register that incorporates the control measures to mitigate the risks.

Figure 2 shows that early identification of closure risks at the planning stage of a mine enables risks to be avoided or closure liability to be minimised using controls built into designs and operating procedures (ICMM 2008).

Figure 2: Risk management practice over the life of the mine

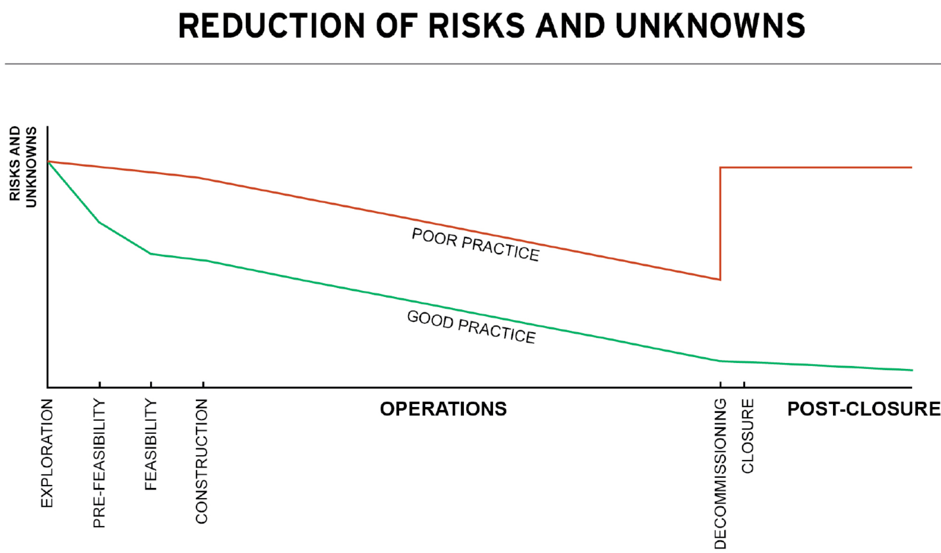
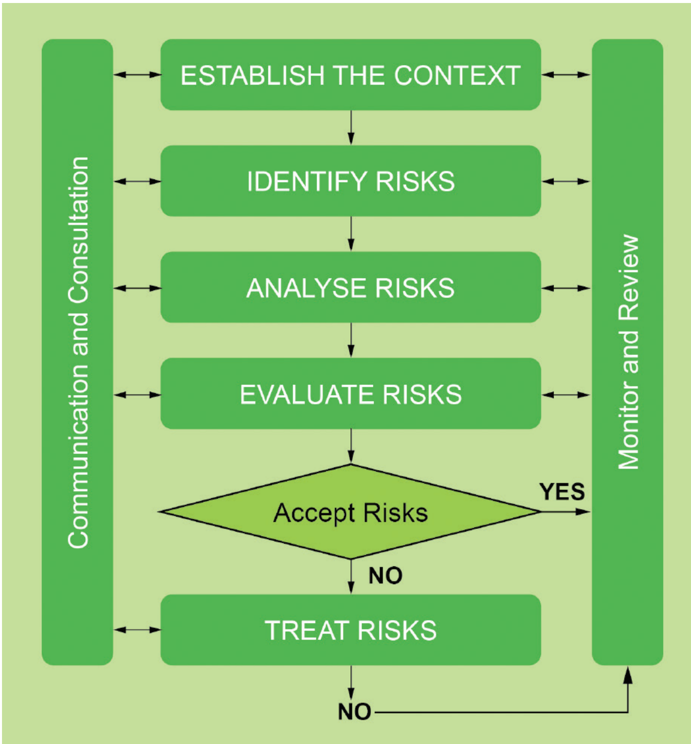


Figure 3 illustrates a method for managing risk as it changes throughout the life of a project or organisation using the process outlined in AS/NZS ISO 31000:2009 *Risk management—principles and guidelines* (Standards Australia / Standards New Zealand 2009). This process is particularly relevant to mine closure planning, as mine closure risk profiles often change significantly throughout the LoM. The standard emphasises the need for continual communication and consultation, review and monitoring of risks.

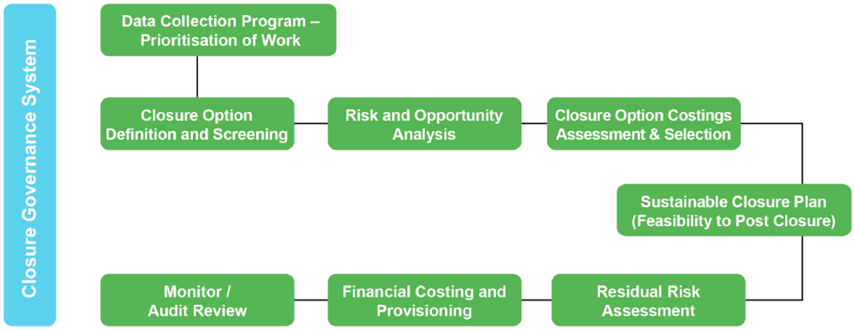
Figure 3: AS/NZS ISO 31000 risk management process



Source: Modified from Mason et al. (2013).

AS/NZS ISO 31000:2009 outlines the need to set the context for each risk assessment conducted. This includes defining how the results of the risk assessment will be used and assists in selecting the right risk assessment tool, level of effort and team for the assessment. It also ensures that the questions posed during the risk assessment are focused towards the purpose for which the risk assessment outcomes will be used. Figure 4 shows that a risk assessment is a useful tool that can be deployed throughout a number of stages of mine closure planning (Standards Australia / Standards New Zealand 2009).

Figure 4: An approach to the use of risk management in closure planning



Source: AS/NZS ISO 31000:2009.

Each of the assessments outlined in Figure 4 has quite different objectives from the others and consequently needs to be planned and executed to specifically meet those objectives; for example:

- risk assessment can be used at the data collection phase to help identify critical gaps in information and prioritise data collection efforts
- at the closure option selection phase, risk assessment identifies the key risks that need to be managed in closure and provides a focus for developing options to manage those risks; however, to develop a sustainable closure plan, the option development and evaluation process needs to be able to factor in opportunities for leaving a positive legacy as well as methods for minimising negative impacts
- during closure cost estimation, risk assessment can be used to identify the costs associated with the occurrence of unplanned events and help formulate appropriate contingency plans
- an assessment of business risks to the organisation from poor closure management or decisions can be used to focus closure effort and develop an appropriate closure governance system.

2.6.1 Closure option development and evaluation

While a useful tool, a risk assessment alone typically only deals with controlling potentially negative impacts to the environment or society. It does not generally encourage a review of how a positive social, environmental and economic legacy can be left after closure, and on its own does not provide a helpful decision-making framework about what value is being provided for a given expenditure.

The value of the post-mining ecosystem or environmental outcome is often subjective and difficult to quantify meaningfully. Natural resource management (NRM) organisations use a number of models to assist in prioritising values associated with an area and to identify the best investment options to protect or enhance those values. Some mining companies are using these approaches to help identify opportunities for leaving a positive legacy and in evaluating which closure options provide the best balance between social, environmental and economic benefits for given expenditures.

Given the difficulty in evaluating post-mining ecosystems or environmental outcomes in absolute terms, most of the NRM models provide a framework for transparently comparing the costs and outcomes associated with different management options. Different options provide different social, environmental and economic outcomes. The NRM models focus on making the trade-offs between different environmental, social and economic values transparent.

In evaluating mine closure options, the use of these models requires mining companies to shift their thinking from onsite post-closure environmental outcomes to how the outcomes relate to a landscape-scale social, environmental and economic context. Typically, the evaluation also needs to be informed by consultation with a variety of stakeholders because human valuation of ecosystem services is poorly understood and is influenced by the social, environmental and economic context of an area.

Models used to assess values associated with a particular land-use or management strategy include ecosystem services evaluation (Millennium Ecosystem Assessment 2005), the Investment Framework for Environmental Resources approach (INFFER 2011), and decision-making frameworks and approaches such as those described by the Australian Coal Association Research Program (Brereton et al. 2012) and Cavaye (2003).

In conjunction with a risk assessment of closure options, NRM evaluation models facilitate a transparent assessment of benefits and costs, and of trade-offs between the social, environmental and economic values offered by each option following closure and completion. They can also be used to identify areas of uncertainty where research or closure/rehabilitation trials may be needed to demonstrate that an option will manage identified risks to an acceptable level, or achieve the societal value expected.

2.6.2 Incorporating risk costs into financial costing and provisioning

Ideally, the closure plan addresses closure risks at acceptable levels; however, there will always be a level of residual risk or uncertainty that requires further assessment and management. These uncertainties include the success or failure of the chosen option, including failures caused by stochastic events such as an earthquake, extreme weather or fire. Given the long time frames involved in mine closure and relinquishment, the residual risk assessment of closure options requires a long-term focus.

The methodology used for estimating the costs associated with the execution of the mine closure plan should factor in the costs associated with addressing the residual risks as a contingency. Additionally, in some jurisdictions in Australia, mines are required to provide a financial bond or surety in some form to cover residual risks arising after the relinquishment of tenements.

2.6.3 Using risk to establish a closure governance system

Decisions made throughout the LoM have the potential to affect the closure liability associated with the mine. The liabilities associated with those decisions are easily overlooked if the focus at the time is one of short-term production gains. One way of focusing attention on the implications of key decisions on closure liability is to consider a business risk assessment on a regular cyclical basis. Typically, such risk assessments consider the full range of risks arising during and after closure as a result of decisions made about mine infrastructure and planning, including environmental, safety, social/community, technical, financial and reputational risks.

To facilitate the comparison of the costs and risks associated with different decisions affecting mine closure liabilities, a business risk assessment typically expresses each category of risk in financial terms. For example, environmental risks arising from closure could be quantified by the costs to the business of:

- remediation of any environmental impacts
- re-engineering landforms to prevent a recurrence of an issue
- fines for noncompliance
- impacts arising from a poor environmental reputation with investors.

A business risk assessment is often used by companies to develop a governance system that focuses attention on those decisions that have the most potential to affect the closure liability of a mine. A long-term goal that requires consideration at the project design stage is the post-mining land use, which needs to be discussed in consultation with relevant stakeholders to prevent an increase in the overall LoM costs.

2.7 The business case for sustainability in mine rehabilitation and closure

One of the strongest business drivers for progressive mine rehabilitation and systematic closure management is the well-documented knowledge of the enormous cost incurred if mining operations are not closed correctly. Non-sustainable rehabilitation at active mines still occurs, despite the example of many inadequately closed mines in Australia and throughout the world. We must research and understand failed closures if we are to demonstrate to the community that mining is one land use in a sequence of land uses.

Undertaking progressive rehabilitation before closure can help to reduce liability while providing increased certainty that a sustainable rehabilitation prescription exists. The business case for progressive rehabilitation is multifaceted, with tangible and intangible aspects. Tangible benefits include decreased financial assurance, compliance with regulatory requirements and more accurate costing for sustainable rehabilitation in closure provisioning. Intangible benefits include those related to timelines and project approvals, when sustainable rehabilitation can be demonstrated and an ongoing social licence to operate demonstrates to external stakeholders that mining can be a valued, responsible and transient land use.

There are also potentially significant barriers to making a compelling business case for early closure planning and progressive rehabilitation. They are generally centred on economic realities, a lack of incentives for getting it right, or a lack of consequences for getting it wrong. For example, the focus on net present value (NPV) by most companies means that there is a strong disincentive for bringing any costs associated with closure forward, including the costs of progressive rehabilitation. Furthermore, while NPV reduces the liability carried at any point in time (potentially by more than 50% in some cases), low interest rates for bank guarantees (0.5–2%) mean that the incentive to reduce liability for purely financial drivers can be a hard case to make. The temptation, given the barriers outlined above, is to do minimal work on closure planning until as late in the LoM as possible.

Leading practice involves the full integration of closure planning and implementation across all stages of the LoM, from exploration to relinquishment. In attempting to make the business case for starting closure planning early, one focus should be on the increasing level of detail that occurs from the initial development activities for a mine, right through to the cessation of operations. This ensures that scarce resources are not wasted by developing too much detail in early plans when fundamentals may change, leading to significantly different closure outcomes. However, this also ensures that planning activities with large lead times are commenced at an appropriate stage in the closure process, with increasing detail as required.

Part of the business case for this is the concept of 'no surprises'—that is, ensuring that all potential risks are identified as soon as possible and managed at the appropriate time in the closure planning process. Risk is an unavoidable consequence of mining operations, and there is a business case to embrace a robust and comprehensive risk management approach. One method of incorporating risk planning into closure planning is to develop a risk register that incorporates the control measures to mitigate the identified risks.

To shift the paradigm on closure planning and progressive rehabilitation requires a multifaceted business case, emphasising the tangible and intangible benefits, an examination of perceived and real barriers, and the ownership and influence of senior leaders in the organisation. Importantly, this often requires environmental professionals who are asked to make the compelling case to change their perspective and view the issue in a new light, informed by the backgrounds of the senior leaders they are trying to influence.

An integration team is often needed to ensure that mining and new landform construction, tailings/washery waste management, infrastructure development, water management and community engagement are integrated around the closure vision. This will ensure that the objectives are clear and the role of each key department is articulated. The team should also be involved in the closure and rehabilitation risk assessment process, so that significant closure risks and control measures are understood.

2.7.1 Progressive rehabilitation

Progressive rehabilitation is an LoM process that enables post-mining land-use objectives to be achieved. Benefits of progressive rehabilitation include:

- reducing the overall unrehabilitated 'footprint' of the mine
- allowing trials of various rehabilitation and closure options and demonstrating rehabilitation success outcomes to the wider community
- showing commitment to stakeholders and employees that the mine has an active mine rehabilitation and closure program
- reducing the overall closure costs
- reducing the risk of failure and ultimate liability
- reducing 'rehabilitation bonds'.

The most cost-effective earthworks are achieved when integrated into the mine plan. For example, when waste rock is being hauled out of an open pit and placed into a landform, it could be transported to an adjacent landform 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 for by the resulting cost-effective and timely progressive rehabilitation.

The nature of the landform surface directly affects critical long-term objectives, such as resistance to erosion, the integrity of encapsulation of hostile wastes, the capacity to accept and store rainfall, and the ability to support plant growth. Ultimately, slope configuration, and the nature of surface material on those slopes, should be interdependent, with slope angle and length being constrained by the relative capacity of the surface material to resist erosion. Vegetation communities are typically one of the most visible outcomes of mine rehabilitation and thus are a logical focus of rehabilitation planning; however, success in establishing the community depends on creating an appropriate soil environment that forms a stable, functional cover.

Unfortunately, in some sectors of the mining industry, the appetite for closure planning and progressive rehabilitation can change rapidly as the financial viability of operations changes. Many of the variables affecting viability, such as commodity prices, foreign exchange and so on, are outside the direct control of the mine operation. However, the effects of such fluctuations can be ameliorated through effective forward mine planning and building progressive closure works into the standard works mining cycle ('the way we go about the mining').

Activities that are essential in the progression of a rehabilitated area towards the agreed closure objectives and completion criteria include post-closure earthworks repairs and maintenance; surface drainage maintenance; revegetation monitoring; caretaking duties, such as fire and weed management; grazing animal management and protection; water treatment systems; and the maintenance and management of ongoing monitoring data.

2.8 Post-mining land-use opportunities

The modern mining industry recognises that mining is a temporary land use. Consequently, there is a responsibility to minimise disturbance, create stable non-polluting landforms, carry out progressive rehabilitation where practicable, and at closure enable subsequent land uses that benefit local and regional communities. Concepts of planned closure and sequential land use are not unique to mining, but are relatively recent developments.

At the regional scale, mining companies can be significant landholders, so both operational and non-operational land should be managed in consideration of neighbouring and future land uses. Closure planning aims to ensure that as much land as possible can be safely and sustainably used for subsequent agricultural and other economic activities or conservation and community use.

It is imperative that the stakeholders and proponent arrive at an agreed set of closure objectives and completion criteria for the site that will allow the company to relinquish the site in a manner that meets regulatory requirements and satisfies community expectations. Commencing open discussion using the legacy framework early in the process (Figure 1) can facilitate a successful outcome.

After mining, the disturbed areas will be rehabilitated, but modern large-scale surface mining inevitably results in substantial transformation of the landscape. As well as physical effects on landscapes, mining projects shape the cultural identity of communities, sometimes over generations. This heritage, industrial and cultural, can be a source of community strength and pride.

Closure plans, therefore, need to reflect local circumstances and build on local strengths, which are potentially an important factor in making a successful transition after mine closure. Fostering trust and good working relationships to secure community involvement and develop a shared responsibility and ownership of post-closure activities should be an objective of closure planning and consultation throughout the LoM. Such trust and collaboration are not likely to materialise if the effort is left until, or after, the announcement of closure.

Options for post-mining land use are many and varied. The Post-Mining Alliance publication '101 things to do with a hole in the ground' (Pearman 2009) compiles examples of post-mining land use that are noteworthy because of their uniqueness (Eden project), aesthetic appeal, spectacle (Butchart Gardens), or simply good design. The book also devotes a section to community-led regeneration, highlighting projects that have had a lasting positive effect on their communities, contrasting with the conventional image of social and economic decline after mines close. Ultimately, a final closure option must be developed that is supported by stakeholders and meets the closure objectives at an acceptable cost.

Case study: Post-closure land use, Woodlawn Bioreactor

Woodlawn Bioreactor—managed by Veolia Environmental Services

Woodlawn was an open-cut (1978 to 1987) and later underground (1987–1998) mine from which zinc, copper, lead, silver and gold were mined. Situated near Tarago, south of Goulburn in NSW, the site had a fairly large iron sulphide ore body from which 13.8 million tonnes of ore were mined, and an estimated 4 million tonnes remain (but not as one consolidated ore body, making further mining unfeasible). In 1998, the then owners (Denehurst Ltd) departed, leaving the site in receivership, millions of dollars of unpaid wages and superannuation, little rehabilitation over a vast site, considerable environmental issues (acid sulphate soils, heavy metals such as arsenic, lead and copper), and an open cut around 800 metres wide and more than 200 metres deep.

In 2002, approval was given to Collex (now Veolia) to develop the mine void as a bioreactor, harvesting the methane from rubbish breakdown to run a small power station to generate electricity. It was estimated that it would take 60 years to fill the site's 25 million cubic metres with rubbish. A waste transfer station near Clyde in Sydney, considered controversial at the time, was constructed, and in 2005 the operation began sending containerised waste by rail to the Woodlawn site.

Early days in the bioreactor's life—the base liner in place in the open cut.

Since that time, the project has continued to grow, and the operation, in concert with the local community, has remained innovative and aspirational. Woodlawn, currently one of the largest and certainly one of the deepest purpose-built bioreactor landfill projects in the world, is now accepting around 20% of Sydney's putrescible waste, and is recognised as an example of best practice landfill technology.

Since its opening, over 3.8 million tonnes of waste has been used to generate green electricity, and the facility now exports enough power to supply more than 2,500 households (Veolia 2016). The bioreactor's capacity is being progressively increased to 22.5 MW. In addition to operating the methane generator, Veolia committed to rehabilitate the mine site over the project's 60-year lifespan.

Advanced development of the bioreactor.

Community outreach continues—with the bioreactor operator providing tours and an onsite education centre where visitors can watch videos about the current operations.

The operation has diversified its integrated operation:

- Its aquaculture and horticulture operations use the waste heat produced from energy generation for fish farming, incorporating hydroponics in the filtration system to remove excess nutrients.
- The Woodlawn Mechanical and Biological Treatment Facility extracts the organic content from the mixed waste stream to produce compost for onsite mine rehabilitation.
- A working farm applies nutrient and grazing rotation to improve meat and wool productivity while reducing impacts on the soil.
- Windfarm (operated by Infigen Energy) is a 50 MW wind farm harnessing the natural energy in an area renowned for significant year-round winds.

Ongoing engagement with the local community includes a community liaison committee, regular updates in the *Tarago Times,* email and SMS alerts, and regular representation at local community meetings.

The Veolia Mulwaree Trust provides funding for charitable purposes and worthwhile community projects to benefit communities within or surrounding the former Mulwaree Shire Council area. Since 2005, the trust has distributed more than $5 million to local community initiatives.

For more information, visit the Veolia website (http://www.veolia.com.au/sustainable-solutions/community-development/woodlawn-bioreactor).

Mining heritage itself often provides post-mining opportunities, such as by enriching tourism, education and other economic activities after mining. In some instances, mining heritage-focused tourism may be one of few post-mining opportunities. Links between mining heritage and other heritage attractions in the same region should be explored. Entire towns and multiple or individual mines (such as at Broken Hill) and their associated infrastructure may have mining heritage values and be heritage listed; this will influence post-mining land-use strategies.

For example, a history in mining, art and culture is part of a formal relationship formed between Broken Hill and the historic mining town of Rio Minas in Spain. The Burra Charter (ICMS 2013) provides guidance for the conservation and management of cultural heritage places in Australia. The charter has links with mining heritage, having been originally adopted in 1979 at the historic mining town of Burra in South Australia.

Case study: An international example of heritage preservation and rehabilitation—the closure and completion of lignite mines in the Ruhr and Saar valleys in Germany

Innovators turn spoil heaps, slag and old furnaces into cultural and commercial centres
For more than a hundred years, hard coal from domestic production was a basis for industrial success in Germany. In 2007, the German Government decided to stop financial support for the coalmining industry from 2018. This led to a final mining closure program over a massive area.

The German hard coal mining company RAG is supporting the restructuring process in the coalmining regions of the Ruhr and Saar valleys through the adaptive reuse of former coalfields. Together with state institutions and local municipalities, RAG aims to activate sustainable development in the mining towns. Mine closure is seen as an opportunity to change both industrial and urban structures in a future-oriented way. Instead of becoming industrial wasteland, former mining areas will become vital places; instead of facing economic decline, former mining towns will prosper.

To create opportunities for future-oriented long-term employment, new, innovative businesses require a good infrastructure: offices, commercial real estate, comfortable and aesthetically pleasing housing, as well as recreational areas and cultural facilities. RAG is using its real estate expertise to help the former coalmining regions progress towards this goal. Such efforts are of particular benefit to would-be owners of small and medium-sized businesses.

The sites of former coalmines often make optimal facilities for logistics service providers with an eye on the future, although they must be centrally located and within easy reach of roads, canals and railroad networks. One such site is the 4-hectare Fürst Hardenberg Logistics Center in Dortmund, built jointly by the RAG Montan Immobilien development corporation and the logistics concern Fiege. In addition to the space occupied by the distribution centre of a multinational tyre manufacturer, an additional 2.3 hectares of logistics space has been leased by a textile discounter and an industrial bread bakery. Five additional logistics centres along the same lines are currently in the planning stages for other projected sites in the Ruhr. Other business parks have been developed at the site of the former Minister Stein and Radbod mines in Dortmund and Hamm, respectively.

Besides business and urban development, keeping the industrial culture plays an important role. People identify their region with the industrial heritage of the coal and steel industries. As those industries declined in Germany, people became aware that industrial heritage formed the cultural mentality of their society and that they had a unique architectural and urban landscape. Many cultural projects and events contributed to the effort by preserving outstanding industrial buildings and sociocultural experiences.

The regional tourist project named Route der Industriekultur ('The Industrial Heritage Trail') promotes a 400-km circular route around the Ruhr area, opening up the region's industrial heritage to visitors. Twenty-five 'anchor points' mark the trail, including six important museums of technical and social history, many lookouts and a series of significant workers' settlements. The trail bears witness to 750 years of industrial history in the region and also to the structural transformation that has been taking place here for several decades. The disused factory sites, many of which are under preservation orders, are not sites of nostalgia and regret. They have long been transformed into lively industrial venues and attractive centres for cultural and tourist events.

The cultural highlight of the year in the Ruhr area is the ExtraSchicht (ExtraShift) Night of the Industrial Culture. Former industrial plants, active production facilities, mines and spoil heaps are skilfully turned into venues of industrial culture and hundreds of thousands of people join this very special event during a long summer night.

Former Minister Stein coalmine (Dortmund): Shafthead frame from 1926 to 1987, office building since 1999.

Source: DRET (2011).

2.9 The community and closure

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 those communities, and also raises the issue of how to maintain or improve the wellbeing and social sustainability of the communities.

In many remote and regional areas, mining operations provide the only significant mainstream economic activity. The establishment of a mining or mineral processing operation almost always brings significant infrastructure to the mine site, to the local community and to the broader region. Hence, industry can play a critical role and contribute to regional economic development through providing training and employment opportunities across a range of professions, skills and services. Community capacity-building projects during the operational phase of a mine require planning and implementing initiatives specific to that community, often in partnership with other stakeholders, to provide long-term positive outcomes.

Stakeholder and community engagement and development are overlapping but distinct processes. Effective stakeholder engagement is an integral part of community development, but engagement can also be undertaken for other purposes; for example, to address community concerns about environmental impacts. Community development likewise involves more than just interacting with the community. The development of programs 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. Liaison between mining companies and the community is important throughout each stage of the mine's operation and a vital part of achieving a positive mining legacy.

2.9.1 Stakeholder engagement

It is often before or during exploration activities that a company commences stakeholder engagement. In some cases, negotiations and the consent of landowners or Indigenous groups are necessary. Like first impressions, the quality of community engagement at this early stage is very important, as it will influence future relationships.

Stakeholder engagement is an important tool in closure planning. Mine closure plans only have relevance in the community and context in which they are designed and communicated. By measuring and monitoring community engagement and development before, during and after closure, the company will have an opportunity to:

- gain agreement from key stakeholders, early in the mine planning process, on the post-mining land-use and completion criteria for a suite of objectives
- gain feedback from all stakeholders on options and alternatives
- build relationships of trust or repair fractured relationships
- maintain its social licence to operate
- help to mitigate dependency
- benchmark the effectiveness of closure and community engagement plans
- enhance the potential for sustainable mine closure
- enhance the opportunities for community development that arise from the active mining and mine closure phases.

Ongoing stakeholder engagement is critical if the community is to have the capacity to transition into closure as smoothly as possible. The *Community engagement and development* leading practice handbook (DIIS 2016b) provides further information and case studies on best practice for effective community engagement and community development programs.

2.9.2 The social licence to operate

A commitment to leading practice sustainable development is a prerequisite for a mining company to attain and maintain its social licence to operate in the community. A social licence has many intangible but significant benefits for business, which, in turn, can profoundly influence the perceptions of communities, NGOs and other stakeholders associated with existing or proposed mining operations.

Unless the community is engaged and supports the mining operation, opposition and confrontation may ensue. Lack of knowledge and understanding often leads to the fears in the community about a mining proposal. Misconceptions commonly result in objections and difficulties that serve no constructive purpose and promote a spirit of non-cooperation. Mining operations run by corporations have been disrupted on many occasions in the recent past, particularly by local artisanal and small-scale miners who were in many cases mining before the larger corporate operations began.

A current example of the difficulties faced by mining companies is the Masbate operation in the Philippines, where small-scale miners regularly tunnel beneath open-pit benches. Blasting or operating machinery on those benches can be extremely hazardous for both company personnel and the small-scale miners.

Dysfunctional community interaction will ultimately distract management from its main focus of efficiently running the mine. Enlightened mining companies, particularly those operating in the developing world, maintain their social licence to operate by undertaking various initiatives, including preferentially employing local people and training and providing skills in businesses or enterprises that will endure after the mine closes.

An example is the Sepon gold–copper operation in Laos, which employs around 7,000 people, most of them from the 70 villages surrounding the mine. The mining company has built extensive training workshops to provide electrical, mechanical, welding, automotive and other skills through apprenticeship and other programs. It has also provided the funding for enterprises such as silk weaving and farming innovations (see case study).

Case study: Community engagement in Lao PDR

Mining brings work, wealth and cultural research to Lao villagers

A range of community and government engagement processes implemented at the Sepon Project in Lao People's Democratic Republic (PDR) from its commencement ensured that effective communication channels were in place to enable continuous change in the project scope. Those changes included the mining of copper as well as gold, the ongoing expansions of both copper and gold resources, the addition of a second tailing storage facility and the construction of a large permanent accommodation camp. These mechanisms have given an initially small mining company the ability to continuously explore and develop while maintaining its social licence to operate in a remote country with no previous history of engagement with multinational mining companies.

Background
Minerals and Metals Group and the Lao PDR Government own 90% and 10%, respectively, of Lane Xang Minerals Limited, which has been operating the Sepon Project in Vilabouly District since initial goldmining approval was granted by the government in 2002. The Sepon Project currently consists of the open-pit mining and processing of oxide gold ore, the mining and processing of various types of copper ore, and the mining of limestone to support copper processing.

Government and community engagement
A steering committee was established by the Lao PDR Government and the Sepon Project team in 2002 to oversee the construction and operations of the project. The committee continues to meet three or four times per year, both at the site and in the capital city, Vientiane, and is attended by representatives of all the ministries and government departments that are responsible for the various aspects of the project. The Sepon Project representatives provide updates on financial, technical, environmental and community aspects of the operation. Questions are raised by both parties and vigorous debate often ensues.

Similarly, a committee consisting of local village and government leaders was established during initial project construction. It usually meets monthly and is attended by senior representatives from all directly affected villages and the Sepon Project, including the site general manager. Matters of concern to the local community and the project, including managing in-migration, ongoing access to land and controlling theft, are discussed and resolved.

Impact assessment engagement
An environmental and social impact assessment is conducted before the development of each project expansion or change. A critical component of the assessments is engagement with villages that will experience impacts on their land or water resources as a result of the change. This has involved meetings in each village, using interpreters who are skilled in local dialects. Separate women's meetings are held to ensure that women's concerns and ideas are included in the assessment and agreed mitigation strategies.

Special-purpose engagement
A range of special-purpose engagement processes have also been established to enable the implementation of agreed mitigation and management strategies. An example is ongoing cultural heritage work involving archaeological surveys, which is guided by a memorandum of understanding between Lane Xang Minerals, the Lao PDR Government and an international university. This has resulted in the excavation, recording and preservation of artefacts of international significance.

Site-based stakeholder engagement, Sepon Project.

Source: DRET (2011).

2.9.3 Consideration of local and indigenous communities in post-closure management and monitoring

One of the most important factors shaping the relationship between mining companies and indigenous communities is the ability of the parties to communicate effectively with each other. The pace of decision-making with an indigenous community living on its traditional lands can be slower than a mining company might prefer; however, without such a process, any expedited decisions might not stand the test of time.

There are commercial and socioeconomic benefits for a project from interacting with local and indigenous communities and businesses during operations. Planning for mine closure should ensure that the future 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.

There are many examples in developing countries and in Australia in which businesses have been established under land access agreements to build capacity and prepare the community for mine closure. The challenge is to provide the community with lasting benefits that are not dependent on the company. Business models need to be sustainable and include capacity building with individuals across the community; early engagement is needed so that as many businesses as possible can move from a single-customer arrangement to a broader client and market base.

Engaging in post-closure management and monitoring tasks not only gives a local or indigenous community the capacity to adjust to the legacy as the mine transitions towards its post-mining land use, but also gives an insight into how those services can be delivered on a broader scale in the region. Although the scale of this work is often inconsequential in comparison with revenues from an active mine, such opportunities should not be undervalued, as they can bind the local community to the site.

Because mining companies and indigenous communities have their own unique cultures, building strong relationships between them depends on each party understanding that the other operates within a very different value system. Without this shared understanding, it is difficult to develop enduring relationships that will enable both cultures to coexist amicably, or to manage effectively the issues that arise when mining companies and indigenous people work together, particularly during the pre- and post-closure phases and into the post-mining land-use relinquishment phase.

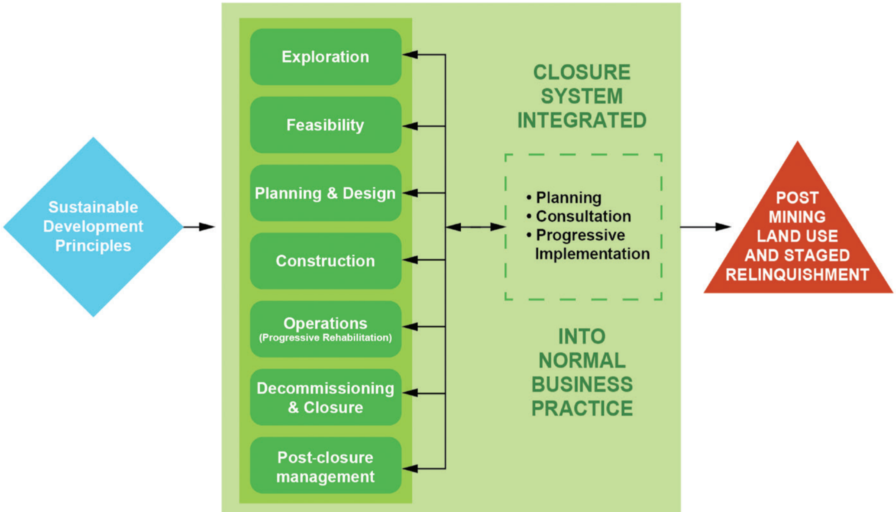
3.0 LIFE OF MINE PHASES

KEY MESSAGES

- Planning for mine closure should be done progressively throughout the various phases of the mining project's life cycle and integrated completely into the company's normal business planning and practice.
- Mine closure and rehabilitation ultimately determine the post-closure land use for future generations.
- The feasibility phase is an integral element of the mine evaluation process in which the implications of mine closure need to be considered accurately.
- The planning and design phase needs to integrate consequences for the environment, future land uses and community health and safety when making decisions on mine closure and relinquishment.
- Leading practice during the operations phase involves progressively allocating financial resources, planning and implementing mine closure and focusing on completion measures and post-mining land use.
- The pre-decommissioning and closure planning stage is critical and requires a focus on aspects of liability, final decommissioning planning, assets and divestment, remediation, legacy infrastructure, and post-closure monitoring and management.
- The decommissioning and closure phase triggers the implementation of the closure plan, which may involve investigations to confirm that the agreed outcomes and completion criteria have been met.
- Even after the bulk of the mine infrastructure has been demolished and removed and the site has been fully rehabilitated, there is a requirement for ongoing management and monitoring of the site until final sign-off and relinquishment are achieved and the new land users take ownership and responsibility.

This section examines the relationship of closure with the seven phases considered to represent the standard LoM. Figure 5 illustrates the phases of a mining project discussed in this section.

Figure 5: Phases of a mining project integrated into a closure system



Planning for mine closure should be done progressively throughout the LoM. The level of detail and focus on particular details will vary through the cycle, depending on which phase the project is in or is transitioning to. For the planning to succeed, the management team needs to ensure that it is systematised early in the LoM and integrated deeply into the normal business planning and practice of the company and that the company ethos adopts closure planning as normal business.

This approach ensures that the practice flows into planning, consultation and implementation rather than being attended to at the end of the LoM. The initial groundwork, even at the exploration phase, can affect the effectiveness and success of closure planning. To ensure optimal results, it is critical that the company and its staff engage in all the steps of closure implementation and ensure that stakeholder engagement occurs strategically throughout the process of planning for mine closure and into the post-mining land-use relinquishment phase.

3.1 Exploration

Mineral exploration covers the initial phases of a prospective mine's life. Mineral exploration and evaluation techniques range from the most environmentally benign, such as remote sensing from satellites, to the more invasive, such as close-spaced intensive drilling.

Exploration activities have the potential to adversely affect the environment if they are not managed appropriately. The application of high-standard environmental management practices in exploration is essential to ensure that such activities are properly controlled, particularly to protect environmentally sensitive areas.

It is often before or during exploration that the company's community engagement begins. In some cases, negotiations and the consent of indigenous groups or other landowners will be necessary. The quality of community engagement at this early stage is very important as it will influence future relationships. There are environmental and social impacts that need to be addressed during this phase, including access tracks, drill pads, disposal of wastes, water management, increased traffic and disturbance, interaction with other land uses, and community concerns and expectations.

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

- the development of relationships with local stakeholders, regulators and the community
- preliminary discussions with key stakeholders on the mine concept and post-mining land use, and the collation of issues that may need to be addressed
- the collection of early environmental baseline data, including surface water and groundwater quality and quantity, soil types, vegetation types, fauna values and meteorological data
- a preliminary assessment for waste rock characterisation during exploration
- record keeping and registers of stakeholder-related matters and resolutions.

3.2 Feasibility

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. Feasibility studies are required in the pre-production stages to justify the continued investment of money in the project. The objective is to clarify the basic factors that govern project success and, conversely, identify the major risks to project success.

The implications of mine closure need to be considered accurately at this stage. Feasibility studies usually consist of a scoping study, a pre-feasibility study and a bankable feasibility study.

Baseline monitoring should commence at the pre-feasibility stage and include all relevant environmental, economic and social issues identified in risk planning.

Surveys and monitoring programs should differentiate between the direct and indirect impacts of the exploration and mining operations, and any other factors that may threaten local and regional biodiversity values. The resulting information is essential for the effective design of management programs and rehabilitation and closure objectives.

Although drilling and sampling focus on ore zones in the exploration and pre-feasibility phases, sampling of host and country rock should increase as the project develops so that adequate data is available to produce block models and production schedules by geochemical waste types.

Knowledge of the likely wastes that will be generated, the materials that will be exposed and the constraints that these factors will place on the mining operation is vital to closure planning (Scott et al. 2000).

3.3 Planning and design

The goal of the planning and design phase is to achieve an integrated mine system design, in which a mineral is extracted and prepared at a desired market specification within acceptable environmental, social, legal and regulatory constraints. It is a multidisciplinary activity.

Mining engineers, mine geologists and consultants generally have the most influence in mine planning and design. They need to understand and take into account mine closure issues and integrate economic, environmental and social elements into the company's decision-making.

It is important that lead times are sufficient to permit the collection of key information to allow sound planning and design decisions to be made. This is particularly important where research on alternative approaches to closure design and rehabilitation options may be needed.

Decisions made during this phase can have long-term consequences for the environment, future land uses and community health and safety, all of which will affect the mine closure and relinquishment process. A risk-based approach (see Section 2.6) 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.

In many Australian states and territories, the regulatory authorities require a closure plan as part of the approvals process. The plan is used to assess the project, the environmental controls required and the long-term potential liability posed by the development of the mine. The closure plan should consider:

- the potential area of disturbance
- sensitive receptors
- volumes and types of wastes to be stored, including waste rock and tailings
- the character of the wastes, including their geochemical properties and acid mine drainage (AMD) potential
- an alternative options analysis and optimisation of selected methods or options
- appropriate locations and the required capacity of water storage facilities for potable consumption, process supply, and site water management
- the geotechnical stability of ground surface and engineered structures
- regulatory requirements for design and closure
- proposed designs for waste storage facilities
- costs to rehabilitate and close
- social and economic development and sustainability issues, post-mining land use and infrastructure, and other community programs.

Mine planners need to balance short-term cost savings against potential long-term issues. For example, a company may make the decision to mine a deposit by open-pit methods rather than by underground methods. This may allow quicker access to ore and therefore earlier cash flow, but it could result in higher volumes of waste and, if the waste is sulphur rich, it may result in acid rock drainage with serious closure consequences, mitigation and management costs. An option to deal with the situation may be the removal of non-target waste sulphides through changes in the design or operation of a process plant to lessen the magnitude of potential acid production in tailing post-closure.

During planning for effective landform construction, some critical information is required in relation to mined wastes, including:

- the estimated volumes of waste material to form the landforms
- the physical, chemical and geochemical characteristics of the soil and waste materials
- preferred material positioning in the landforms to accommodate material characteristicsthe volumes available (for example, those materials that may be suited to placement near the surface, and those that may be best contained deep within the body of the landform)
- the sequence and timing of different materials being made available via the mining schedule.

The nature of the site, and the degree to which there is choice for the location of the waste landform, makes every landform unique. If possible, it is important to consider to consider the footprint location ahead of that of infrastructure placement as the location of the landform can have multi-million dollar implications. Critical factors in location include:

- proximity to the open-pit exit or exits
- the gradient of the footprint area, both for the direction of drainage from the landform and for the dumping costs
- placement in relation to natural drainage, and where possible avoiding blocking natural surface flow, or accommodating drainage beneath the landform
- footprint constraints (tenement leases; future ore bodies; priority flora, fauna and ecological communities; cultural heritage sites; and current and future infrastructure)
- topography, visual impact and the opportunity to complement the local landscape
- the stability of underlying material.

Understanding the timing of waste material flow by type and the preferred location for all materials is a key element in determining whether a landform plan can be achieved.

3.4 Construction and 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. The influx of a construction workforce can provide economic benefits to the local community, particularly to local businesses, but it can also put pressure on local services and have a negative social impact on the community. It is essential that construction contractors and personnel understand the implications that their activities can have for adjacent communities.

Construction activities typically include building or installing:

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

It is during the development and construction phase of the LoM that many long-term decisions are made, all of which influence final decommissioning and closure works. Possible factors with implications for closure and relinquishment include the following:

- Poor foundation construction for a TSF or water storage ponds can lead to exacerbated long-term seepage and potential groundwater contamination.
- Waste rock storages designed to handle sulphide waste need to have appropriate low-permeability foundations, acid-consuming material placed as a basal layer, or both.
- Limited surface water management planning with poor erosion control during construction can result in large sediment loads travelling offsite during rainfall.
- Proper storage and handling of fuels and lubricants and sound workshop management can reduce contamination from storages and spillages.
- Proper identification and handling of topsoils and other growth media, and control of dusting from stockpiles, can assist immediate and long-term environmental management.

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. Sustainability requires that the complex relationships between various risks be well understood, especially the potential for links between environmental, social, political, economic and reputation risks.

3.5 Operations

Once production begins, the mine is said to be in the operations phase, which can extend for many years, typically from five to 20 and, in some cases, more than 50 years (for example, large iron ore, coal and bauxite mines). During this period there will be operational changes, plant expansions and progressive rehabilitation. There could also be changes in ownership with potentially different management approaches.

In the regular refinement of the mine closure plan, the company needs to focus on the long-term goals (objectives) and post-mining land use. All activities should be directed at supporting the long-term goals.

Leading practice involves progressively allocating financial resources and planning and implementing mine closure and completion measures during the operational phase. This includes allocating financial resources and a team of appropriately experienced people to engage with the community and other stakeholders on the operation's closure.

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

- The **operations commissioning stage** is the period after construction is completed. It can typically include initial production commissioning; start-up and pre-stripping for open pits; the development of declines and shafts; or the construction of waste rock landforms and TSFs.
- In the **mature operations stage,** most of the disturbance has taken place and the mine is in steady production and operations. It is important during this phase that experienced personnel are involved in overseeing the construction and placement of deleterious material in landforms. Failure to maintain quality control in this phase of the mine operation can jeopardise environmental protection during operations and following closure.
- Known ore resources are exhausted as the **pre-closure planning stage** approaches. However, the length of this stage is often unpredictable; it may rapidly increase or decrease depending on ore reserves, discovery, or unforeseen events that drive an unforeseen closure. In some Australian states and territories, there is a requirement to develop a detailed decommissioning and closure plan two years before the closure of the site. The plan must incorporate the demolition of infrastructure, final landform earthworks, revegetation and the commencement of a post-closure monitoring program. The development of a closure plan is detailed in Section 5.

3.6 Decommissioning and closure

Decommissioning and closure involve the implementation of the closure plans developed in the earlier stages. In this phase, it may also be necessary to conduct investigations and studies to identify potential contamination and to confirm that the agreed outcomes and criteria have been met.

At the time of mine closure, most of the preparatory work needed to protect the environment has been done as part of a well-conceived closure plan which has been progressively updated and implemented throughout the operations phase.

Mines can close unexpectedly during the operations phase for many reasons, such as process failure, unforeseen ore limitations, a collapse in commodity value, budget overruns, community opposition and outrage, significant unexpected environmental impacts, or perhaps a combination of such factors. A case study example is the Bottle Creek Mine in Western Australia.

Case study: Unplanned closure

The Bottle Creek Gold Project is 95 km northwest of Menzies in the Northern Goldfields of Western Australia. 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, a run-of-mine pad and two tailings storage facilities were established during the operational stage of the project.

In May 1990, Norgold Limited submitted a proposal to rehabilitate the site 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 afterwards, 300 mm of cyclonic rainfall resulted in significant erosion and gullying on the landforms. The DME asked Norgold to undertake appropriate rehabilitation works to repair the damage caused by the cyclone.

In September 1996, Norgold requested that DME release the bonds. The environmental inspector raised a number of tasks that needed to be done before the bonds could be retired, including remediating erosion gullies, reseeding poorly vegetated areas, battering down-slope angles (on some of the remaining structures), applying topsoil to several areas, and backfilling drillholes. Two subsequent joint site inspections were made, in October 1996 and in June 1997. Norgold was asked to submit a new rehabilitation plan to detail how, when and to what standard it would do the remediation works required by the DME. In November 1997, Norgold submitted a new rehabilitation plan. The work was completed by May 1998. DME made another site inspection in May 1998 and identified further small works.

In November 1998, Norgold submitted a compliance review as well as a monitoring report that included a validation of the rehabilitation undertaken and of the developing ecosystem using ecosystem function analysis. This monitoring system, developed by Tongway and Hindley of CSIRO (http://csiropedia.csiro.au/systems-developed), reports on the condition of the ecosystem by comparing the level of functionality displayed by the rehabilitation with that at control or analogue sites in the surrounding region.

A closure inspection in December 2000 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 the 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 and 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 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 ecosystem function analysis data from the fixed monitoring transects at the site.

This case study of unplanned closure demonstrates 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 from the regulator.

Further details about this case study are in Anderson et al. (2002).

Bottle Creek mine site before and after rehabilitation. Source:

Source: *Mine closure and completion* handbook (2006).

For the company to move successfully into the post-closure phase and relinquish the mine site with all its obligations for future maintenance and funding discharged, it is essential that:

- early establishment of verifiable completion criteria has occurred (this is critical to receiving acceptance and approval for relinquishment by the regulator)
- a robust and verifiable process is in place to monitor and demonstrate completion criteria.

It can take considerable persistence by a company to achieve relinquishment, particularly if early rehabilitation is inadequate for the task. The quality of mine closure planning will become apparent once the last tonne of ore is passed through the processing plant and it is shut down. At that stage, the key people on site will be the closure manager and the closure team.

Activities (which can run for some years) in this phase include:

- demolition and removal of infrastructure
- consolidation and decommissioning of the tailings facilities
- reshaping of remaining mining landforms
- re-establishment of surface hydrology and drainage systems
- treatment, discharge or disposal of poor-quality water
- completing the rehabilitation and remediation processes
- managing, monitoring, recording and documenting closure processes
- measuring the performance of closure activities against the agreed closure objectives and criteria and reporting that performance
- inspections, consultation and reporting to stakeholders on progress
- staged and progressive community and government sign-off.

A systematic process of data recording and management during decommissioning and closure is vital for the closure planning team in understanding the status of the closure work and issues.

3.7 Post-closure management and monitoring

Even after the bulk of the mine infrastructure has been demolished and removed and the site has been fully rehabilitated, there is a requirement for ongoing management and monitoring of the site. This phase continues until final sign-off and relinquishment are achieved and the new land users take ownership and responsibility.

Since common closure problems such as AMD can have a long lag time before they become evident, it may be necessary to monitor the success of revegetation, the effectiveness of cover systems and any impacts on water resources for many years until good evidence of stability is on hand and relinquishment can be obtained from the regulator.

While leading practice involves early definition and agreement of completion criteria and progressive sign-offs, some criteria may need to be monitored for an extended period (possibly 10–20 years).

Consideration needs to be given to how to resource this phase of the closure process, as there are many tasks to consider, such as logistics, personnel, safety, and responses to change. Retaining company staff or caretakers to attend to post-closure management may require the retention of offices, amenities and equipment but can be cost-effective, rather than looking to others external to the site who may lack site knowledge and have large mobilisation costs.

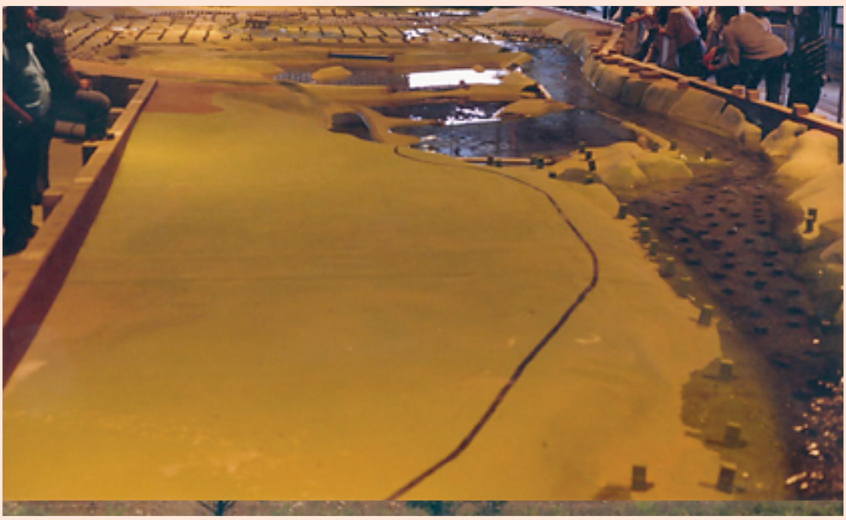
Companies responsible for some closed sites may have to retain a medium- to long-term presence on site due to requirements, particularly those related to long-term water treatment. Other activities at this stage may include:

- ensuring that the site is as safe as possible, given that the mine area becomes gradually more inactive
- appropriate or new safety protocols for site access and the installation of adequate security to limit access and prevent vandalism
- review of any failed decommissioning or rehabilitation activities
- continued monitoring and reporting on rehabilitation and closure targets against the agreed closure objectives and closure criteria
- provision of monitoring and other information to the regulator and stakeholders as part of the agreed and appropriate format to obtain sign-off (this may be via progressive community and government sign-off on long-lead closure criteria targets)
- relinquishment of mining leases and legal transfer of ongoing responsibility to post-closure stakeholders and land users.

Case study: Post-closure land use, Penrith Lakes, NSW

Rehabilitated mine sites have become wetlands, water storage dams, tourist sites, golf courses, fish farms, water ski and windsurfing parks, motor sport complexes, amphitheatres and even rowing courses. One of the largest examples in Australia was used for the 2000 Olympics rowing events, which were held in rehabilitated gravel pits near Penrith.

Penrith gravel pit rehabilitation in progress (October 1990).



Physical scale surface water model for Penrith Lakes development (October 1990).

Previously rehabilitated Penrith gravel pits (October 1990).

Those generating post-mining land-use options first need to consider factors such as climate, topography, soils and adjoining land use. Consultation on the specific issues of post-mining land use with neighbours, local authorities and special interest groups is also a fundamental part of the process.

Each site should be assessed for its post-mining use. Sustainability is an important factor: the ongoing use should continue to be beneficial to the local community and the environment, and the land-use model needs to ensure that the site does not become a liability for the community.

In some cases, options for ongoing land use will be limited by economic, legal and technical constraints. For example, where deep voids or open cuts have a surrounding zone of instability, it would not be appropriate to consider options that attract people into the area. The first priority must always be to protect the environment and public health and safety by using safe and responsible closure practices. Engaging stakeholders in deciding decommissioning options assists in a focus on the long-term economic and social sustainability of communities associated with the mine legacy.

Source: *Mine closure and completion* handbook (2002, 2006).

4.0 CLOSURE PLANNING

KEY MESSAGES

- 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 early during planning.
- An understanding of the likely wastes that will be generated, the materials likely to be exposed and the constraints that these factors will place on the mining operation is vital to closure planning.
- The management of water through all phases of the mining cycle is as critical to closure as the management of mine waste.
- Characterisation of mine waste materials should commence as early as the exploration phase and continue through the pre-feasibility, feasibility and operational phases as a basis for mine closure planning.
- Final placement of mine waste in constructed landforms that are both physically and chemically stable over the long term should be done as early as is practical, and progressive rehabilitation should take place whenever it is viable.
- Mine tailings rehabilitation and closure require a unique focus.
- In planning for a tailings storage facility, leading practice operators consider mine closure from the beginning of the project development and consider all aspects of tailings disposal while developing and maintaining a TSF decommissioning plan.
- The preparation of a radiation management plan that augments the closure plan is required for the closure. It should include a program of ongoing monitoring and surveillance to be put in place once closure has been satisfactorily completed.
- It is essential that extensive investigations be carried out during the feasibility, planning and design phases to identify and quantify key surface water and groundwater management issues.

Making the best technical and social decisions in closure planning requires the collection, assessment and management of environmental, social and economic data, which has to be adequately managed so that it is easily retrievable and accessible.

Mining engineers, mine geologists and consultants generally have the most influence in mine planning and design. They need to understand and take into account mine closure issues and integrate economic, environmental and social elements into the company's decision-making. For mine closure planning to be successful, the management team needs to ensure that mine closure is integrated early into planning rather than being attended to at the end of the LoM. One example seen all too often is the construction of waste landforms without a detailed understanding of the physical and geotechnical properties, chemical composition and geochemical characteristics of the mine waste.

An understanding of the likely wastes that will be generated, the materials likely to be exposed and the constraints that these factors will place on the mining operation is vital to closure planning. For example, the appropriate storage of highly reactive or metal-rich waste material may incorporate encapsulation or selective placement within a waste landform. Decisions made during the feasibility, planning and design phases can have long-term consequences for the environment, future land uses and community health and safety, all of which will affect the mine closure and relinquishment process.

Leading practice can only be achieved through early recognition of potentially problematic mine waste materials, including those that are physically and chemically hostile to plant growth or have the potential for acid mine drainage and other types of mine drainage. The nature and composition of the ore and host rocks differ at each mine, so the potential risks of chemical and geochemical contamination, and risks to the physical integrity of constructed waste landforms and rehabilitation success, will also differ.

The management of water through all phases of the mining cycle is as critical to closure as the management of mine waste.

This section links the characterisation of prospective waste materials and process residues (tailings), and the potential risk of future contamination of the environment, with appropriate design of waste landforms. Experience has shown that appropriate landform design needs to incorporate the management of surface water and have the capacity to achieve target completion criteria.

4.1 Physical, chemical and geochemical characterisation of mine waste

Irrespective of the residual risk, the goal of characterisation is to determine the likely physical behaviour and chemical reactivity of the waste material under the conditions in which it will be stored, the constituent elements present, and their likely future speciation and mobility.

Characterisation of mine waste materials should begin as early as the exploration phase and continue through the pre-feasibility and feasibility phases as a basis for mine planning, and needs to include baseline concentrations of significant analytes and pertinent geochemical values for likely downstream receptors.

It is essential that the characterisation of wastes continues during the operation of the mine, particularly where the ore grade and mine plan change, for example in response to altered market conditions. Samples, derived from drilling activities, should represent each geological unit that will be mined or exposed and each waste type for current and projected mine plans, to represent adequately the variability or heterogeneity within each geological unit and waste type. Attention should be paid to any localised mineralisation in the host rock that will be sent to the waste landform. Volumes and types of wastes to be stored should be reviewed throughout the life of the mine, as in the earliest stages of planning the estimates may be only tentative.

Geochemical analysis should include total sulphur content as a minimum, and include key potential contaminants in all drill core assays. Potential chemical contaminants will be site specific, but may include a range of metals and metalloids (such as arsenic and selenium) in addition to the main economic target minerals. In addition, a variety of parameters may be measured to assess both the current acid status of waste and the extent of potential acid generation. Standard procedures of acid–base accounting and net acid generation testing are routinely applied in assessing both the acid-generating potential and the acid-neutralising capacity of the waste. The combined results may be used to indicate that the material is potentially acid-forming, although careful interpretation of all aspects of the chemical and mineralogical composition is needed to confidently predict the scope for chemical contamination.

Different sulphide minerals, and different combinations of sulphides in a given rock type, oxidise at different rates under identical environmental conditions. Geochemical characterisation should be complemented by the determination of chemical and physical parameters and mineralogy that will influence the rate of oxidation and acid production. Mineralogical investigations should examine the type and mode of occurrence of sulphide and carbonate minerals. Attention should also be paid to benign waste materials that may be used in the construction of physically sound and chemically stable waste landforms. Key attributes include the erodibility of the materials and their potential to support plant growth.

4.2 Mine drainage issues

Acid mine drainage (AMD) is the sum product of acid-generating reactions (sulphide oxidation, metal hydrolysis) and acid-neutralising reactions. Carbonate minerals are the most effective and fast acting neutralising minerals. However, all but the most resilient silicates and oxides lend some degree of acid neutralisation, given enough time.

While AMD is the most ubiquitous problem, the potential to generate drainage of higher pH must be recognised; for example alkaline leachate is possible in the case of high-magnesium rocks and fly-ash. Mine drainage of circumneutral and alkaline pH may contain significant quantities of metals and metalloids where it results from previous neutralisation of metalliferous AMD.

The main goal of waste management in terms of geochemistry must be to counter, as far as possible, the reactions that produce acidity and metals in aqueous solution. The main way to do that is to limit the exposure of the wastes to water and air. Where waste must temporarily stay at the surface before final storage, the prevention of the initiation of AMD is of critical importance. In addition to minimising exposure to water and the atmosphere, the education and involvement of the workforce in recognising the earliest manifestations of AMD is recommended. Rapid remediation of AMD is important to prevent excessive acidification before remediation becomes impractical or cost prohibitive.

Irrespective of acid production, preventing the weathering of mineralised waste is beneficial to minimise the liberation of metals into solution. The most effective way to restrict the exposure of reactive wastes to oxygen is to deposit them permanently underwater, which works because of the limited amount of dissolved oxygen in water. However, water covers are only viable when an assured volume of water is permanently available.

Additional information on the characterisation and selective placement of materials is in the leading practice *Mine rehabilitation (*DIIS 2016c) and *Preventing acid and metalliferous drainage* (DIIS 2016d) handbooks.

4.3 Engineered landform design and construction

Landforms of mine waste are the most obvious physical remnant of mining operations. Reflecting this, they are an important element in rehabilitation, closure and relinquishment, so they should be safe, stable and appropriately vegetated and pose minimal ongoing environmental risk. Historically, the key design focus has been to minimise haulage costs; in many cases, the design and construction of landforms has involved only limited consideration of closure requirements and at best has been based on known technologies of the day.

The final placement of mine waste in constructed landforms that are both physically and chemically stable over the long term should be done as early as is practical, followed by progressive rehabilitation whenever viable. Key elements of a successful landform design include:

- the comprehensive characterisation of the properties of soils, overburden and mineral processing wastes to determine their potential erodibility, capacity to support plant growth and potential to have adverse impacts on water quality
- the segregation and selective placement of those materials to ensure the creation of a favourable medium for plant growth and the protection of water resources
- the incorporation of surface water management into the design.

Wastes that need encapsulation are more likely to be encountered at depth, and the nature of open-pit mining dictates that they will be mined towards the end of operations. A detailed understanding of the mining and associated dumping schedule will enable the encapsulation and other selective placement of soil and waste materials to occur through planning, landform design and monitored construction. Formal audits should review waste material placement, landform development and rehabilitation in relation to the plan, and include updated information on waste types and volumes as mining progresses.

A key objective of landform planning is to place waste materials in the right place, at the right time, to protect the environment and the long-term land use at the least cost. In most circumstances, establishing sustainable ecosystems after mining requires the conservation and replacement of soil over the mined area. Segregation and selective placement of overburden layers are used to bury material that is injurious to plants or that may contaminate water and to salvage materials that can be used in the rehabilitation program.

Poor outcomes of landform construction include:

- excessive erosion, which potentially compromises the integrity of cover layers and can result in the movement of sediment into the surrounding environment
- poor establishment of vegetation due to unfavourable material properties
- poor vegetation development due to inadequate water-holding capacity, nutrient deficiency or chemical toxicity
- longer term issues, such as deep drainage through hostile stored material.

The slope of the landform surface and the nature of the soil and mine waste materials directly affect critical long-term objectives, such as resistance to erosion, the integrity of encapsulation of hostile wastes, the capacity to accept and store rainfall, and the capacity to support plant growth. Remediating existing landforms to correct problems caused by the inappropriate placement of mine wastes can be extremely costly.

Waste rock is often incorporated into the surface of outer batter slopes to reduce the erosion potential and enable an operation to construct relatively long, high slopes without berms. Another option is to create concave slope profiles, which can substantially reduce erosion potential.

Managing surface water on constructed waste landforms is vital to minimise concentrated, erosive water flow. Ensuring that landform designs account for extremely heavy rainfall is a critical element. In general, the erosion of constructed landforms on mine sites is by gullying after water-control structures fail. The reasons for failure include inaccurate construction, tunnel erosion and overtopping due to the deposition of sediment. In arid areas where surface vegetation is too thin to protect the soil surface, rates of slope erosion can remain high. In such circumstances, outer batter profiles that include berms (rarely sustainable) may need regular maintenance (de-silting) as long as the erosion continues in order to prevent sedimentation leading to overtopping and gullying.

The effective functioning of landforms and meeting completion criteria critically require geotechnical stability; resistance to erosion; appropriate management and disposal of excess water during storms; storing potential infiltration while minimising impacts from deep drainage; and ensuring the availability of soil moisture for vegetation.

If water does not need to be excluded from the mass of the landform, the design of the surface layer can focus on facilitating infiltration, vegetation requirements for soil moisture and erosion management. If water must be excluded, several factors need to be considered, including slope configuration, managing run-off water, the capacity of surface materials to accept and store rainfall, evaporation and transpiration by vegetation, and preferential flow paths.

It is possible to develop a landform design that minimises costs in operations and at closure, and that also poses the least risk to the surrounding environment. Strategies using a block model approach to landform construction are a powerful tool for mine closure, in that they create a practical interface for environmental constraints to be combined with, and influence, mining engineering and economics.

4.4 Mine tailings

The Australian National Council on Large Dams takes a particularly strong view of TSF planning in relation to risk management:

> The objective of planning is to ensure a commitment to managing an appropriate level of risk during all phases of the life cycle of a tailings dam, including concept development, design, construction, operation, decommissioning, rehabilitation, ongoing monitoring and the extended post-closure period. (ANCOLD 2012)

TSFs are designed to be geotechnically stable and safe during operation, and for their stability to increase after mine closure. However, in that context, tailings are recognised as one of the most easily mobilised materials that remain after a mining operation. Pollution can be mobilised from impoundments through a number of mechanisms, such as in airborne dust, in liquid or semi-liquid form, and in water as suspended solids and dissolved materials (Envec 2005).

Issues associated with the closure of TSFs are often complex and require a detailed understanding of the physical, biogeochemical and geochemical nature of the specific tailings and the facility in which they are stored. Identifying problems and potential risks early in the LoM can guide closure planning towards a particular design and end point.

In planning for a TSF, leading practice operators:

- consider the closure of the facility from the very beginning of the project development, 'designing with closure in mind'
- broadly consider all of the aspects of tailings disposal relative to the many variables in the operation's environment
- consult broadly and appropriately before selecting the tailings disposal technique and the location, type and design for the TSF, consistent with operating the facility to its final closure

- develop the methods for tailings disposal, managing disposal, annual auditing, and proactively managing the facility to produce an operating manual and emergency response procedures
- develop and maintain a TSF decommissioning plan, which incorporates a clear vision of the final landform design and the land-use objective, and regularly review that plan and its applicability.

A TSF may evolve over a number of years during operations, and vary from the original plan as the operator and designers adjust to optimise the dynamic economic and functional process of the mine and its tailings disposal. Because ore sources, ore grade and the mine plan change, potentially resulting in changes in tailings geochemistry, it is imperative that the characterisation of tailings and cover materials continues throughout the life of the mine.

The operator needs to provide a methodology for that design review process, and operational constraints have to be identified and incorporated into operational procedures. A principal aim should be to operate the TSF towards achieving closure and allowing its intended use after closure (Bennett and Lacy 2012).

According to ANCOLD (2012), closure and rehabilitation planning should ensure that the tailings disposal area is left in such a way that it is able to:

- maintain an acceptable impact on the environment
- be structurally stable
- be resistant to deterioration through erosion or decay
- be compatible with the surrounding unmined landform
- be functionally compatible with the agreed post-mining land use.

Experience shows that decommissioning is most effective if approached systematically by a team of highly experienced people from appropriate scientific disciplines to facilitate a sustained and effective planned closure (Lacy and Barnes 2006).

Due to the complexity of TSFs, regulators recommend the development of a conceptual decommissioning plan for each one. The plan presents a detailed assessment of the current status of the facility and any further engineering works proposed as part of its final closure and rehabilitation. As a minimum, engineering, geotechnical and environmental specialists are needed; hydrologists (groundwater and surface water) and geochemists are needed to provide a complete and adequate conceptual decommissioning plan.

TSFs often are the source of significant post-closure risk and become negative legacies. However, technology in tailings disposal continues to evolve, such as through developments in the thickening of tailings to make efficient use of space in TSFs, efficient water use and the long-term stability of rehabilitated tailings and residue dams (Jewel 2005).

The subject of tailings closure, decommissioning and rehabilitation is covered in more detail in the leading practice *Tailings management* handbook.

Appendix 3 of this handbook lists issues, consequences and options in relation to TSF impacts.

Case study: Tailings disposal, rehabilitation, closure and completion at a bauxite mine in Western Australia

Dry stacking pays dividend for Alcoa

Alcoa World Alumina Australia currently produces 7.3 million tonnes of alumina annually at its Western Australian refineries at Kwinana, Pinjarra, and Wagerup. The refineries use bauxite mined in the nearby Darling Range. This ore is low grade by world standards, as two tonnes of residues are produced for every tonne of alumina extracted.

Storage of this residue poses some major environmental challenges. The refineries are close to major population centres and adjacent to some of the state's most productive land, the volume of waste produced is very large, and the alkalinity of the waste has the potential to affect valuable surface water and groundwater.

There were a number of environmental and process reasons why the storage of low density 'wet' tailings in large impoundments was not the preferred technique for future tailings storage.

Development work began in the early 1980s on alternative techniques, and in 1985 'dry stacking' was adopted for Alcoa's Western Australian refineries. Dry stacking uses a large diameter superthickener to de-water the fine tailings, which are then spread in layers over the storage areas to de-water by a combination of drainage and evaporative drying. By using the coarse fraction of the tailings for the construction of drainage layers and upstream perimeter embankments, the storage area can be constructed as a progressive stack, avoiding the need for full-height perimeter dykes and allowing continued stockpiling on areas that were previously 'wet' impoundments.

Routine ploughing of the mud with mechanical equipment has been termed 'mud farming'. Mud farming helps achieve a maximum density that allows the dry stack to be developed with maximum outer slopes (a minimum strength of 25 kPa is achieved, allowing an outer slope of 6:1 to be maintained) and maximises the storage efficiency of the stack.

Mud farming also minimises the potential for dust generation, which is important, given the location of the refineries close to residential areas. Ploughing the surface presents a wet surface, buries carbonate, and provides a surface roughness that prevents dust lift-off once the tailings have dried.

Dry stacking bauxite residue is now fully operational at all three of Alcoa's Western Australian refineries. A number of operational techniques have been developed to optimise the slurry distribution and drying processes, and those have now become standard practices. The advantages of reduced environmental risks and lower overall storage costs are now being realised.

Using a D6 swamp dozer to enhance the drying rate.

Source: DRET (2011).

4.5 Radiological aspects

Radiological aspects are considered not only for uranium and thorium mines but for any mineral-related operations involving naturally occurring radioactive materials, such as phosphate, mineral sands or rare earth operations and oil and gas facilities.

When considering the radiological aspects of the closure of a mining or mineral processing site, it must first be determined whether the site is to be closed permanently or temporarily, and whether the work of closure is a 'planned action' or an 'existing situation', as defined by international standards. The answers to those questions will help set the bounds for the remediation standards to be adopted, as will the selection of a post-mining land use.

Once the land-use objectives and the appropriate standards for the post-closure situation have been determined, they can be incorporated into the site's closure plan. Regardless of the site being classified as a 'planned action' or an 'existing situation', it is important to understand that the radiological protection requirements for the workforce carrying out the remediation work will be the same as for any other classified radiation workers in a 'planned action'.

Guidance on the assessment of radiological risk and standards to be used during remediation works and achieved at completion is in material published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA 2005) and the International Atomic Energy Agency (IAEA 2002).

A radiation management plan that augments the closure plan must be prepared for the closure and should include a program of ongoing monitoring and surveillance to be put in place once closure has been completed satisfactorily. The plan must be approved by the regulatory authorities and should include the radiological end points to be achieved in terms of dose rates and say how compliance with regulatory limits is to be demonstrated.

Leading practice management of the radiological aspects associated with any site goes beyond managing operational risk. It should ensure that relevant objectives and post-closure standards are identified and incorporated into the closure plan at an early stage. This should ensure that all stages of the mining operation are integrated into working towards an approved and acceptable outcome after closure and final relinquishment.

4.6 Water management

Water is integral to virtually all mining activities and is typically the prime medium for carrying pollutants into the wider environment. Consumption of water by mining operations can also be a major source of community concern, particularly in areas that rely on agricultural or other water-intensive industries. Consequently, sound water management is fundamental for all mining operations: recognising water as an asset with social, cultural, environmental and economic value can mean the difference between operating at a profit and operating at a loss.

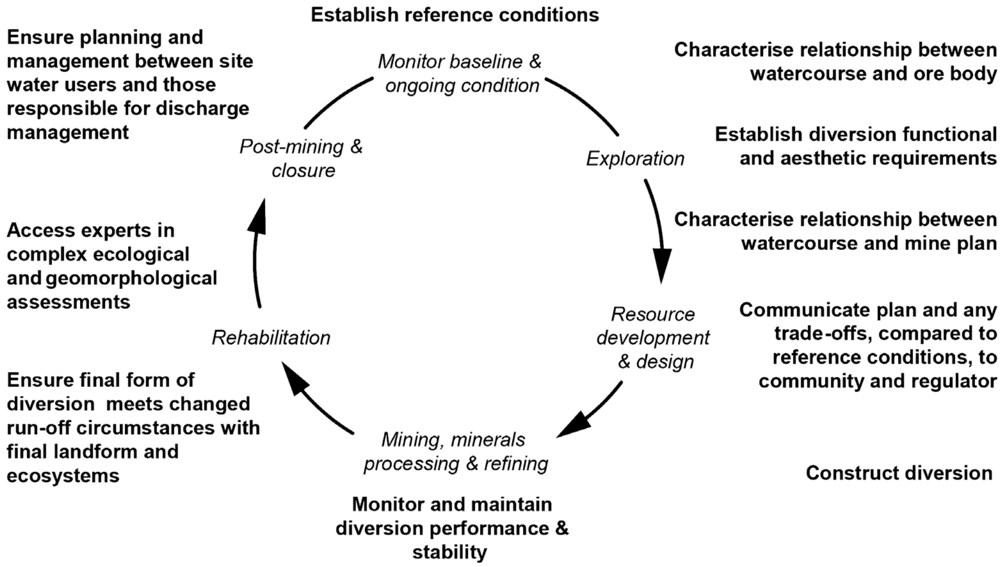
It is essential that extensive investigations be carried out during the feasibility and planning and design phases to identify, determine and, if possible, quantify the following:

- an initial benchmarked baseline evaluation of the water resource at the operation
- impacts of water abstraction or diversion on local water resources and users
- requirements for government approval and regulation
- the design of water supply, storage and treatment systems
- volumes for dust suppression and from de-watering discharge
- whether any specific water management plans are needed for individual areas of the operation
- wastewater disposal
- site stormwater management
- long-term quality and quantity impacts on the surrounding water resource after closure
- community expectations during operations and after closure, including communicating the extent to which they can be met and recording the process.

Mining results in permanent changes to the landscape that can alter its hydrological function. This may have significant long-term consequences for the surrounding environment after closure.

To access the mineral resource in surface mining operations, it is sometimes necessary in the development stage to divert a creek or river around the workings. Leading practice design of watercourse diversions will reduce the time and cost associated with the approvals process. The main activities that must be undertaken to plan for and implement a diversion at various stages during the life cycle of an operation are shown in Figure 6.

Figure 6: Significant issues in designing and managing a watercourse diversion across the life of an operation



Diversions are similar to drainage structures in that their functional aim is to route flow around and away from the operation in a safe, predictable and efficient manner. Natural watercourses are dynamic (prone to flooding and channel instability), whereas diversions must be stable, contain flows and not affect flood levels to an unacceptable degree; it is preferable that the diversion does not act as a physical barrier to the migration of aquatic organisms.

It is also critical that surface water drainage patterns do not damage the integrity of any landforms that remain after closure. Agreement must be reached with key stakeholders on the ability of the company to reinstate or manage, where practical at closure, the surface drainage patterns to be consistent with the regional drainage function.

During the closure process of the New Wallsend coalmine near Newcastle, NSW, one of the major technical challenges required innovative techniques, including the re-establishment of a 500-metre section of Maryland Creek (see case study).

Case study: New Wallsend Mine closure project—Maryland Creek re-establishment

On 24 December 2002, mining ceased at New Wallsend Mine in Newcastle, NSW. The mine was owned by the Newcastle Wallsend Coal Company, a 100% subsidiary of Oakbridge Pty Limited. With its purchase of the majority of shares in Oakbridge in March 2000, Xstrata Coal Pty Limited committed to undertaking site rehabilitation, despite not having mined a single tonne of coal. Xstrata merged with Swiss commodities trader Glencore Group in May 2013.

Closure works—Maryland Creek re-establishment

The closure required innovative techniques, including the re-establishment of a 500-metre section of Maryland Creek. The creek was originally piped through the site to provide for additional coal stockpiling facilities.

Preparations for Maryland Creek re-establishment.

As part of the reconstruction of the creek line, a flood plain with a meandering low-flow channel incised through the centre was established. The design of the creek considered the nature of the channel upstream and included the construction of a similar pool and riffle sequence as well as a riparian structure. Xstrata went beyond compliance by placing inert capping material over the creek excavation to prevent the exposure of potentially unstable material (coal reject) through which the creek was re-established.

Reconstruction on creek line.

The project represented a change to the traditional creek construction and diversion works widely used by the mining industry. The design was developed in consultation with relevant regulatory agencies and relies on the replication of natural processes to ensure long-term stability. The riparian vegetation has become self-regenerating, and little maintenance work (erosion repair) has been necessary since the closure.

Significance of the project

The re-establishment of Maryland Creek has been a significant part of the overall success of the New Wallsend Mine closure project. In 2006, the project was awarded the NSW Minerals Council Environmental Excellence Award and, in May 2007, Xstrata Coal was given approval to commence lease relinquishment, which was within two years of the completion of closure activities.

New Wallsend Mine closure: before (left) and after (right).

Source: DRET (2008:76).

The effective management of groundwater is also a critical item to be considered during the mine planning, operation and closure phases. Knowledge of the baseline groundwater environment is essential for effective mine planning to identify de-watering needs, provide water supplies for mine construction and operations and understand the requirements for aquifer protection and closure.

Groundwater assessment studies generally require the establishment of a monitoring network early in the mining cycle. Through the collection of data and information, a conceptual site model can be developed. This will assist in understanding the groundwater flow, water quality and aquifer hydraulic parameters, such as hydraulic conductivity and storativity, that aid the development of site groundwater models where they are needed.

Conceptual and numerical groundwater models can be used to assess the inflows to a pit or void, to determine potential contaminant pathways, or simply to determine the location and availability of water supplies. Groundwater assessments and modelling studies can prove to be a cost-effective planning tool for all stages of the mining cycle.

Critical to closure is the monitoring, auditing and review of surface water and groundwater through all phases of the mining cycle; these processes support the ability to develop and meet agreed target completion criteria.

5.0 DEVELOPMENT OF A CLOSURE PLAN

KEY MESSAGES

- A mine closure plan should reflect corporate standards and principles and regulatory guidelines and provide a suitable basis for estimating the cost of closure.
- The plan should include a description of the site's planned closure activities and contain the objectives and criteria that form the basis for assessing proposed closure options, and indicate what the company commits to achieving at closure.
- Environmental data from baseline studies undertaken during the exploration, feasibility and planning and design phases is necessary to identify potential environmental issues and to assist the decision-making process throughout the mine's operation and closure.
- After effectively assessing the closure risks and opportunities, a mine closure plan can be used to manage risks to an acceptable level.
- Completion criteria can be defined as rehabilitation performance objectives and should ideally be drafted in the planning phase of the mine in consultation and agreement with key stakeholders. The criteria should be reviewed regularly.
- Ongoing field-based research, monitoring programs and reviews are critical during planning and at key changes in the operation's production plan.
- Applying leading practice and sustainable development principles during the feasibility stage is the key to demonstrating competency, realising the potential value of the resource and building trust with the community and government.
- The closure plan is advanced to a decommissioning plan when exploration cannot define further viable measured reserves and mine management is able to set a likely closure date.

A mine closure plan should reflect corporate standards and principles, and regulatory guidelines, and provide a suitable basis for estimating the cost of closure. The plan should include a description of the management of the site's planned closure activities and contain objectives and criteria that are the basis for assessing proposed closure options and identifying key performance indicators.

The objectives of a mine closure plan are to:

- enable all stakeholders to have their interests considered during the mine closure and for agreement to be reached on post-mining land use
- ensure that the process of closure is orderly, cost-effective and timely
- ensure that the cost of closure is adequately represented in company accounts and that the community is not left with a liability
- ensure clear accountability and adequate resources for the implementation of the plan
- establish a set of indicators that will demonstrate the successful completion of the closure
- allow the company to meet agreed completion criteria to the satisfaction of the regulator.

A mine closure 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 evolve throughout the life of the mine and must provide more detail as the mine nears decommissioning and closure. To maintain credibility and community acceptance, it is imperative that the information in the mine closure plan is accurate and relevant.

5.1 Collect environmental baseline data

Environmental data from baseline studies done during the exploration, feasibility, planning and design phases is necessary to:

- identify the potential environmental issues to be managed through the mine closure process
- establish baseline conditions for closure monitoring programs, including the identification of control and reference sites
- investigate and define the relevant environmental values
- assist decision-making throughout the operational life and into closure
- establish achievable and measurable closure objectives and completion criteria.

A geospatial database, such as GIS, is useful from the outset in data gathering, as all the sites investigated can be accurately recorded and all the information gathered can be linked to this spatial database. In this way, knowledge can be readily updated and accessed over the LoM.

The collection of data on the following environmental factors should be considered as a minimum for any operation, not only to assist closure planning, but to identify which elements need to be monitored or investigated further during the LoM:

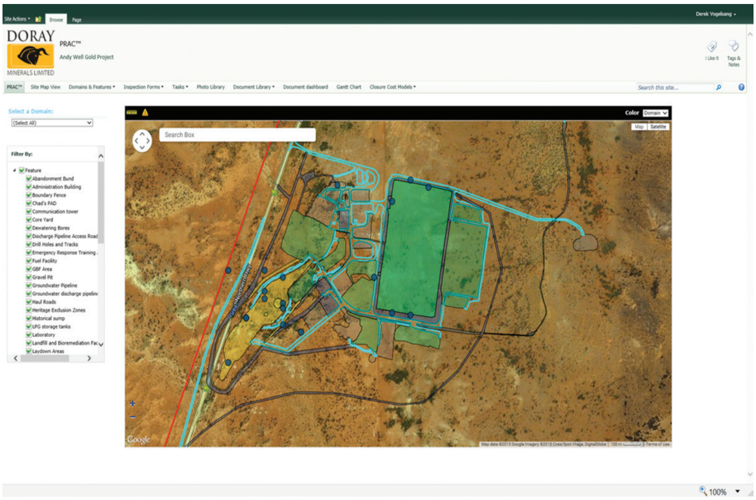
- climatic conditions
- topography, geology, soils
- surface hydrology, hydrogeology, vegetation
- fauna
- subterranean fauna
- biological resources (topsoil seed bank)
- socioeconomic resources, including cultural heritage.

Collecting a set of baseline data enables the operator to establish a regional context for the potential impacts of the operation. It is important that the collection of environmental data is ongoing to enable the database to cover the spatial and temporal variations observed in nature. This data will enable the operation to incorporate natural variations into the setting of completion criteria. Cumulative impacts should also be assessed and reported.

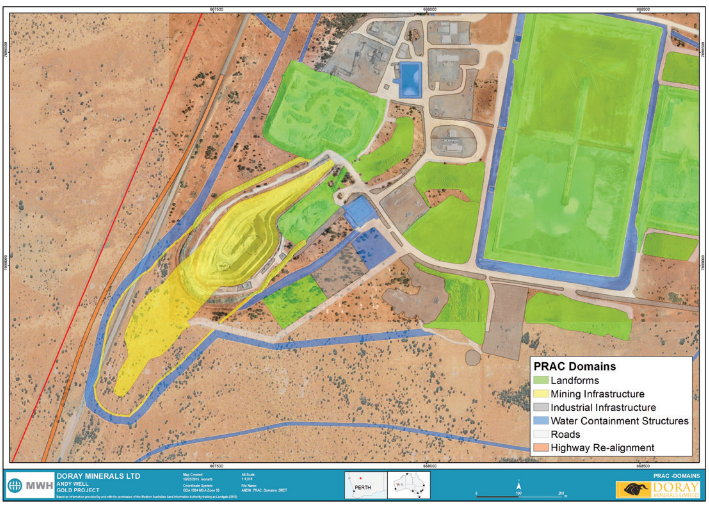
Information on socioeconomic conditions is needed to ensure that closure planning for the biophysical environment takes account of the local community, its current and likely future demographic patterns and current and future land uses.

5.2 Develop a knowledge base for domains and features

To facilitate effective mine closure planning, the operation should be divided into a number of physically distinct domains, a concept developed in 1988 at the Red Dome Mine (McCarthy et al. 1998). Domains comprise features that have similar rehabilitation and closure requirements. An example of a domain could be water containment facilities composed of features such as process water ponds, turkeys' nests and evaporation ponds, which would all have similar closure and decommissioning tasks. The following images show the domains and features outlinedat the Doray Minerals Andy Well Mine within the Progressive Rehabilitation and Closure (PRAC™) web-hosted closure management system and a view of the Andy Well Mine with the domains colour coded.



Domains and features outlined at Doray Minerals Andy Well Mine within the Progressive Rehabilitation and Closure (PRAC™) web-hosted closure management system.



View of the Andy Well Mine, with domains colour coded .

A detailed knowledge base developed for each feature provides a comprehensive summary for each domain. The knowledge base should capture the current status of the particular feature and incorporate the history and technical information such as design information, construction reports, operations manuals and specialist reports, in addition to all available rehabilitation information and monitoring data.

The ongoing development of the knowledge base for each feature enables the mine closure plan to be used as an effective management tool. For example, a mine waste inventory, detailing the volumes and characteristics of waste materials to be generated during operations, will be captured within the knowledge base. This inventory enables the mine planners to assess the availability of materials for use as a rehabilitation resource, and enables the operator to make informed LoM closure planning decisions, as they can review the potential erodibility of mined waste materials and their ability to act as a surface or near-surface rehabilitation medium.

Once the knowledge base has been detailed and documented, a gap analysis can be undertaken. Research and investigation tasks and trials are developed to close out the knowledge gaps. Early identification of knowledge gaps helps guide any research and development programs needed to demonstrate the effectiveness of unproven rehabilitation strategies. As more detail becomes available in the updated knowledge base, the knowledge gaps can be progressively closed. Ideally, the position of all waste types within the constructed waste landforms should be planned for and recorded; the knowledge base identifies whether that has been done. An example of a research and investigation task, in a case where encapsulate wastes are potentially acid-forming, metalliferous, or both, could be to develop a geological and geochemical database to show baseline conditions and the risk of AMD.

The risk associated with the knowledge gap also needs to be ascertained. This risk triggers consideration within the closure risk assessment and the development of controls to mitigate the risk. A risk register will help the closure planning team to understand the likelihood of the closure risk. It can be used in conjunction with a data recording and management system that keeps track of the status of the closure issue.

Case study: Premature closure of a mine with biodiversity, environmental and cultural values

The Timbarra goldmine is 30 km east of Tenterfield, NSW. Ross Mining began the mine's 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 NGOs 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 began 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 were also 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, NGOs, landholders, Aboriginal communities, 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. Studies initiated to support the closure plan included:

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

The findings of the 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 before being finalised and was exhibited publicly. Submissions received from the public were reviewed and negotiated and an addendum to the plan was developed. This was then approved by the NSW Minister for Mineral Resources in November 2002. The plan was 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. The 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 closure 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 a facilitator.
- Engage in (and resource) conflict resolution, rather than avoid conflict.

Reconstructed wetland basin, Timbarra goldmine.

Barrick Gold acquired the mine in 2006 and continued the rehabilitation and closure program. Barrick successfully relinquished Timbarra in 2013, after the company was able to demonstrate that the site had satisfied all mining lease relinquishment criteria.

Source: *Mine closure and completion handbook* (2006).

5.3 Assess residual risk

Ideally, the closure plan reduces closure risks to acceptable levels; however, there will always be residual risks or uncertainties that require further assessment and management, including the success or failure of the chosen option, cost forecasting, and the risk that an event such as an earthquake, a cyclone or unusually high rainfall may occur. For example, a particular water treatment process or waste landform 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 as-planned water treatment system could fail, requiring additional measures. Failure could be due to changes in chemistry, damage from an earthquake or changed regulations that apply stricter discharge limits. Even in cases of low severity and unlikely residual risk, analysis should be carried out from a long-term risk management perspective. A risk-based closure plan identifies and assesses residual risk, and the outcomes are included in the costing methodology.

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

5.4 Develop closure objectives and completion criteria

Closure objectives must set out the long-term goals for closure outcomes. Those objectives should be based on the proposed post-mining land use and be as specific as possible to provide a clear indication to government and the community of what the company commits to achieving at closure.

Objectives for closure can be structured in a range of ways. Some sites or companies recommend high-level objectives for the overall closure plan, and then much more detailed objectives and completion criteria for the rehabilitated areas. The chosen structure for the closure objectives should be tailored to the major risks associated with the closure of the site.

Mining is only a temporary land use, and a clear rehabilitation objective consistent with the projected future land use of the area must be defined. Most Australian regulatory agencies have four general rehabilitation objectives:

- safe to humans, domestic livestock and wildlife
- non-polluting
- stable
- able to sustain an agreed post-mining land use.

These should be seen as minimum objectives, and more site-specific rehabilitation objectives should be developed for each defined land use.

Governments also want successful rehabilitation to ensure that they are not inheriting an ongoing liability and that a liability will not be transferred to private landowners or the next land user, in the case of public lands. Completion criteria should ideally be drafted in the planning phase of the mine, in consultation with key stakeholders, and then regularly reviewed as research, monitoring and progressive rehabilitation are undertaken. The ability to specify completion criteria depends on the amount and quality of the environmental data collected at that time.

Completion criteria can be defined as rehabilitation performance objectives. They represent milestones in the biophysical processes of rehabilitation that provide a high degree of confidence that the rehabilitated mine site will eventually reach the desired sustainable state (the rehabilitation objective). Completion criteria indicate the success of rehabilitation and enable the operator to determine when its liability for the area ceases.

The first step in developing completion criteria is to define guiding principles that allow more specific site criteria to be developed. Principles for the development of completion criteria need to:

- be SMART (Specific, Measurable, Achievable, Realistic, Timely)
- be outcomes-based and linked to the end land use
- be flexible to adapt to changing circumstances
- evolve as the LoM progresses
- include environmental indicators suitable to demonstrate that rehabilitation is trending positively
- undergo periodic review
- include a measurement approach that details how the criterion will have been met.

Completion criteria need to be specific to circumstances (social, environmental, economic and site specific). For example criteria developed to meet a landform rehabilitation objective are developed with knowledge of the waste characteristics, and appropriate analogues are selected based on soil types.

Measurable criteria evolve as the LoM progresses. They are initially qualitative but become quantitative through a process of adaptive learning, following targeted research and analysis of data. The company needs to demonstrate that its early and progressive rehabilitation is adequate and robust, and that it understands what can be achieved. It is essential that monitoring of the criteria can demonstrate achievement of the closure objective.

The second step is to define the time categories under which each completion criteria principle needs to be assessed. An example of defined time categories might be:

- development and mining
- planning and earthworks
- vegetation establishment (0–2-year-old rehabilitation)
- monitoring and closure (>2-year-old rehabilitation).

While it is important to meet the requirements of the state government regulator that will ultimately sign off rehabilitation areas against completion criteria, other stakeholders should be considered in the development of site-specific rehabilitation completion criteria (for example, adjacent landholders, local government and NGOs). Identifying relevant stakeholders and gaining their agreement on the site-specific rehabilitation completion criteria are a critical step in closure planning.

Rehabilitation can be considered successful when the site can be managed for its designated post-mining land use without any greater management inputs than other land in the area being used for a similar purpose.

5.5 Specify monitoring regime and performance indicators

The analysis of success and failure in mine rehabilitation, closure and completion is essential if leading practice is to be accurately defined and demonstrated. In the absence of independent and rigorous review, the same mistakes play out again and again, but the documentation of knowledge about successes and failures (possibly in in peer reviewed journals), prevents new generations of mining personnel having to relearn what is already known.

Monitoring programs that are ongoing post rehabilitation need to be established to assess real-time and historical performance. They can be implemented during all phases of the operation, but are of considerable value when planning a major change to the project or at a key point in the operation's production plan (such as a delayed start date, an expansion or reduction in production, or the suspension of operations) as they provide proof that effective progressive rehabilitation and closure activities are ongoing and in place.

Typical monitoring programs that support a mine closure program include:

- baseline monitoring in the early LoM to define the values that need to be protected or re-established, including by identifying or establishing unmined reference areas during pre-mining mapping and surveys
- understanding, monitoring and recording all potential impacts during the operational phase
- documenting rehabilitation operations to confirm that agreed procedures have been implemented and to aid the interpretation of later rehabilitation monitoring results
- assessing early monitoring data from research and field trials implemented during progressive rehabilitation to determine the best techniques, identify problems and develop solutions.

Monitoring in the first year of rehabilitation evaluates initial establishment success. This leads into long-term monitoring, which continues on into the post-closure period, usually using the same initial techniques for some years after rehabilitation, to evaluate progress towards achieving the closure objectives and completion criteria, and to determine whether the rehabilitated ecosystem is likely to be sustainable over the long term.

If post-relinquishment monitoring is required, consideration needs to be given to who is responsible, the extent of the monitoring and the information needs of stakeholders. Responsibility for post-lease relinquishment monitoring needs to be determined as part of the mine closure plan.

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

The monitoring program should be planned and documented in such a way that it is a straightforward matter to adjust the program when changes to the operation occur. A key feature is the measurement of variables and performance indicators to identify potential modifications to processes. Rigorous review of the data collected by a monitoring program, conducted at appropriate intervals, is needed to ensure that the program remains fit for purpose and enables impacts to be measured.

5.6 Conduct research and trials

In many cases when the mine closure plan is being developed, there may be insufficient information to develop a clear methodology that can be applied to meet the closure goals. The industry has conducted many poorly designed and resourced experiments and trials that resulted in little information being fed back into the global pool of knowledge about mine closures, whereas quality research and trials can provide companies with valuable multiple net benefits.

To produce high-quality research results, people should take the following points into account at the planning stage:

- Determine whether the research is to be conducted via experiments or trials.
- Evaluate the purpose and the problem to be investigated in detail—understand the null hypotheses, boundaries and limits to the project; avoid introducing too many variables; and replicate appropriately.
- Clearly understand the potential 'value' to be gleaned from the project.
- Quantify and evaluate the magnitude of economic loss if the project fails due to poor design, investment or process.
- Decide whether the work will need to be 'highly defendable', publishable, or neither.
- Evaluate how hypotheses are to be statistically tested or the project is to be evaluated.
- Adequately plan and provide appropriate resources, scientists, finance, realistic time frames and reporting.

Examples of site-specific knowledge gaps which may require investigation include:

- the development and/or refinement of soil and waste material inventories (detailing volumes and characteristics of materials)
- waste landform designs (subject to change throughout the LoM)
- TSF and waste landform cover designs (trials and evaluation)
- constructed slope parameters for waste landforms (slope configurations and surface materials)
- weed ecology and management process trials
- recalcitrant species research
- field-scale geochemical weathering evaluations
- surface water management and erosion studies
- revegetation trials on disturbed areas, waste landforms and tailing facilities
- habitat reconstruction for fauna, flora and landscape (such as river or stream diversions).

In these circumstances, specialist expertise is often required to develop a suitable assessment or research program to address knowledge gaps and meet the long-term closure objectives. Field-based research trials, established to evaluate various options under field-scale conditions, are often the best way to identify the most appropriate rehabilitation and mine closure protocols. Information derived from field-based research can often be used to augment existing information or strengthen modelling results.

In many instances, climatic conditions have a strong influence on research outcomes, particularly in field-based investigations. Field-based trials should be evaluated for a period appropriate to the mine environment to capture information under a range of climatic conditions. Heavy rainfall or drier than average years provide opportunities for rigorous testing of the research design parameters.

Research programs can take several years to establish, monitor and modify before acceptable outcomes are achieved. It is critical that the necessary investigations are established long before the mine closes so that the knowledge gained can be incorporated into the final rehabilitation design and mine closure plan.

Case study: Community relationships and the closure of a mine in Indonesia

In 2001, a partnership was established between Kelian Equatorial Mining (KEM), the West Kutai community and the Indonesian Government to negotiate and agree on all aspects of decommissioning and relinquishing the Kelian goldmine. The partnership occurred during a period of civil unrest in a country undergoing enormous political and social changes, and with no legislation to guide the process. The outcomes from the partnership have not only informed best practice for mine closure elsewhere in the world but also guided the development of closure legislation in Indonesia.

Background

KEM was a medium-sized goldmine producing around 400,000 ounces per year that operated for 13 years from 1992 to 2005. Approximately 2,000 local community members (mostly alluvial miners) were relocated (some forcibly) to an adjacent town, Tutung, before the mine's construction. During peak production, the mine employed around 2,500 employees and contractors, including a 5% expatriate workforce mainly from Australia. Post-mining land-use options and ongoing maintenance activities and governance arrangements were determined through consultations involving government, community and mining representatives that were directed by a mine closure steering committee and four working groups over three years.

A detailed charter setting out the roles and responsibilities of the committee members was negotiated and agreed before technical discussions. The charter also included mechanisms for reaching agreement and resolving conflicts.

Closure outcomes

Minimising the ongoing impacts of acid rock discharges, particularly manganese, into the surrounding water catchments was the key driver for the selection of post-mining land-use options for the single-pit, acid waste rock disposal areas and tailings dam areas. A constructed wetland of 20 hectares provides a passive treatment system for pit discharges and enables manganese levels to meet agreed discharge (2 mg/L) and ambient water quality (0.5 mg/L) standards at release points and in the Kelian River, respectively.

The areas that could not be rehabilitated with trees (a total of 829 hectares) have been offset by rehabilitating other areas of equivalent size. Other disturbed areas (376 ha) that did not contain potentially acid-forming materials and could be rehabilitated were planted with local native tree, shrub and vine species, with 10% native fruit trees. These rehabilitation areas permit a range of activities in accordance with forest protection legislation, including:

- harvesting of non-wood products such as fruit, honey, bamboo and rattan
- educational activities such as research and field visits
- aquaculture and fishing
- ecotourism (for example, birdwatching, bushwalking, swimming).

During the operation of the mine, a farmer training centre was established in a village about 30 minutes from the mine site. The centre provided offsite technical support and onsite accommodation and training to local farmers and employees who wanted to improve their farming skills and practices. Since the mine closure, it has been converted into an agricultural high school with boarding facilities that currently has more than 100 students from surrounding villages who are completing a nationally recognised three-year senior high school course.

A post-closure endowment trust fund of US$13.4 million was established in an offshore account in Singapore, generating around US$600,000 per year. The fund is used to support the ongoing monitoring and maintenance of permanent mining-associated structures in protected forests and to provide ongoing administrative and maintenance support to the agricultural high school. It is intended that the funds will operate in perpetuity, in accordance with the agreements and governance arrangements negotiated by the mine closure steering committee.

Rehabilitation of waste dumps at Kelian goldmine.

Source: DRET (2011).

5.7 Review closure strategies and plans

Throughout the mine's life, closure strategies and plans need regular reviews to ensure that they are appropriate, address the major issues for closure, and remain aligned to community expectations and regulatory requirements. To ensure optimal results, it is critical that community and other stakeholder engagement occurs throughout planning for mine closure. The reviews are ideal opportunities for engagement with stakeholders.

The closure plan is a key reference document, 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.

Because every mining project and community is different, research is needed to address gaps in knowledge and develop innovative solutions to problems. Together with the feedback from trials and monitoring, the information gathered through research linked to leading practice monitoring principles is a key element of the continuous improvement loop.

Audits are used to evaluate compliance with regulatory requirements, company standards or other adopted systems and procedures. This helps industry to demonstrate its performance to stakeholders and encourages continuous improvement.

Each review is an opportunity to collate information about the project, update the knowledge base, apply improved knowledge and capture any changes that have taken place since the previous review. It also provides an opportunity to verify the content and outcomes of the closure plan, including:

- closure risks—verify that closure risks have been correctly identified and prioritised
- closure outcomes:
  - minimise the likelihood of negative consequences of closure
  - maximise the positive benefits of closure
  - minimise the likelihood that closure goals cannot be met
  - maximise the likelihood that opportunities for lasting benefits are captured
- completion criteria—revise criteria and progressively move from qualitative to quantitative criteria
- stakeholder engagement—opportunity to re-open.

The closure plan should be in front of mine planners and decision-makers at all times when they are making decisions, so it must be accurate and relevant to maintain credibility and acceptance. In order for the closure plan to reflect the current mine plan, a tri-annual review during the operational phase is considered wise practice (this frequency is often reduced as the mine approaches closure). Regulators may also request that the mine closure plan be updated when a significant change to the LoM is sought. In line with the phases of the operation outlined in Section 3, it is recommended that the closure strategy and plan be collated, reviewed and updated at each of the following stages in the LoM.

5.7.1 Feasibility study

The conduct of the operator at the feasibility stage is critical to maximising future shareholder value. If the operator cannot establish and maintain the trust of the community and government, the potential value of the resource is unlikely to be realised. The application of leading practice and sustainable development principles is the key to demonstrating competency and building trust. Getting this wrong may lead to:

- limited access to the resource (less potential profit)
- delays in approvals and licensing (greater costs)
- refused approvals.

Additional information and data should be available at this time to enable feasibility studies to be completed. That information will enable the development of a closure strategy and knowledge base and identify knowledge gaps for each feature. This will result in the formation of a closure plan and the ability to make informed decisions during the feasibility study to ensure that long-term impacts on closure outcomes are understood and included.

The closure plan that is developed during the feasibility phase must remain a 'living document' as the mine proceeds, with regular reviews and updates based on new technologies, stakeholder inputs, changing mine conditions and community expectations.

5.7.2 Project planning and design

Information collected to prepare the environmental impact assessment will enable earlier closure risks assessments to be reviewed and will facilitate the development of closure objectives, completion criteria, performance indicators and commitments. The project planning and development phase is a critical time when changes that can potentially affect the whole project take place rapidly.

5.7.3 Project construction and commissioning

Project construction is a dynamic phase as changes and variations to design take place constantly to enable construction to progress. On the completion of construction and commissioning, the closure plan needs to be reviewed to capture any changes that have taken place and note how they affect the closure outcomes.

To be effective, the review must be informed by accurate and representative information and data. A review at this stage typically:

- confirms that materials have been placed correctly
- verifies that spills and drainage are being managed and will not contribute to pollution
- confirms that processes and materials used are performing as expected and planned
- verifies that structures are placed and built as planned
- confirms that topsoil, growth materials and closure construction materials have been set aside, are protected from impact or inadvertent use, are accessible and are adequate to meet closure requirements.

5.7.4 Operations

All aspects of the production operation that will affect closure should be monitored to ensure that operational standards and outcomes have been met and that closure will not be compromised. Operational, technology and economic influences drive change at a mine, making it a highly dynamic and constantly changing environment.

Any substantial alterations to the mine operating plan or operating process, including expansions (pit cutbacks, new open pits, waste rock landforms or TSFs), should trigger a review of the closure plan and risk assessment. Regular reviews of the knowledge base, knowledge gaps and associated risks for each feature enable the operation to effectively manage closure planning in such a way that liabilities associated with changes in status or conditions are fully accounted for during the LoM. As progressive rehabilitation is undertaken, these liabilities are reduced. In this way, there is a focus on the liabilities early when there is an opportunity to mitigate them concurrently and cost-effectively during operations rather than when the resource is exhausted or during an unplanned closure.

A review of the underlying risks to the business and its closure should be undertaken with each review of the plan to confirm that the risk controls remain appropriate and that the risk exposure has not materially changed. This can be done using the risk-based approach outlined in Section 2.6.

The collection of appropriate and accurate data through monitoring programs is critical to the assessment or identification of emerging risks, to the assessment of impacts to closure outcomes, and for potential updates to closure-related objectives and completion criteria.

5.7.5 Pre-closure planning

At a point in the mine's life, exploration will be unable to define further viable measured reserves and mine management will be able to determine a likely closure date. During this phase, the closure plan is advanced to a decommissioning plan. All the aspects of the closure plan that are only partially advanced are enacted, including individual landform plans; plans for maintenance, demolition or removal of infrastructure; rehabilitation; safety and social obligations; release of staff and retention of key people; stakeholder consultation; reporting and recording; and final definition of the post-closure management phase. The development of a decommissioning plan is discussed in detail in Section 7.

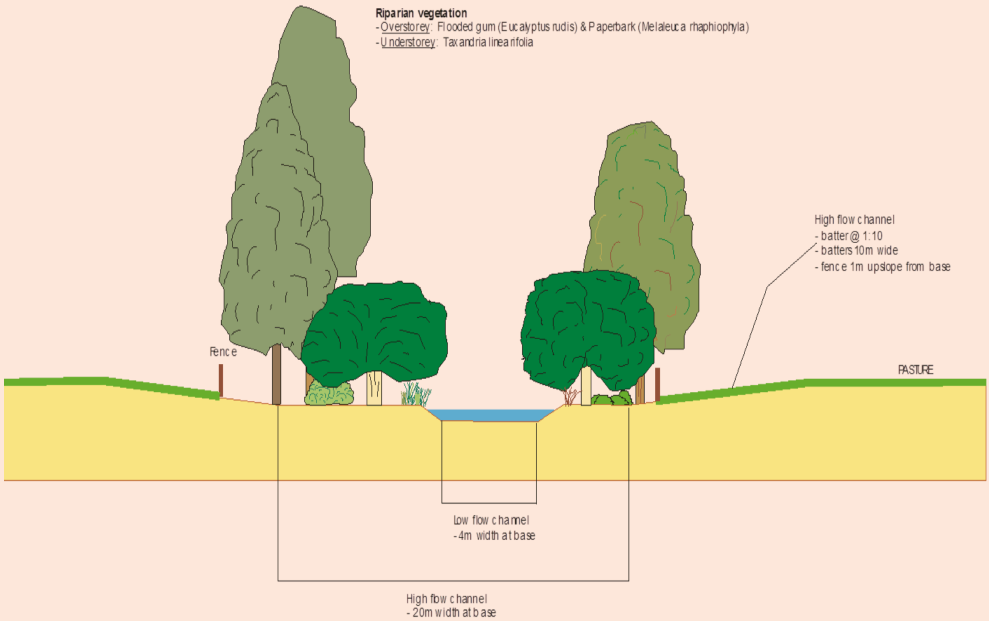
Case study: Iluka Resources returns previous mineral sands mine to productive farmland and ephemeral waterways

Between 2004 and 2009, Iluka Resources Ltd mined the Yoganup mineral sands deposit near Capel in Western Australia's south-west. During the operational life of Yoganup, the company mined 12.9 million tonnes of ore and produced 1.9 million tonnes of heavy mineral concentrate from the site, which had previously been productive dairy farm land. The mine site also hosted two main watercourses: Tiger Gully and the Ludlow River. Before mining began, the streams had undergone modifications including the cutting of meanders and the deepening of channels, which had led to erosion problems. Although there was some fringing vegetation before Iluka began mining the area, most of it had been heavily degraded.

Pre-mine Ludlow River, showing the degraded vegetation and channel deepening.

As part of its mine plan, Iluka developed a surface water drainage management system to enable progressive mining at Yoganup and reconstruction of the two waterways.

To ensure best practice in its operations, Iluka consulted with 15 landowners, 10 neighbours and local and state governments. Local interests and environment groups were also approached for advice. Discussions with these stakeholders resulted in an agreed soil return plan and stockpile-handling methods. A resultant farm use plan was established and signed off by the landowners.



Riparian Vegetation

Trees
- Paperbark *(Melaleuca rhaphiophylla)*
- Marri *(corymbia calophylla)*
- Flooded gum *(Eucalyptus rudis)*
- Swamp sheoak (*Casuarina obesa*)

Shrubs:
- Swamp peppermint (*Taxandria linearifolia*)
- Peppermint (*Agonis flexuosa*)
- Teatree (*Astartea fascicularis*)
- Wiry wattle (*Acacia extensa*)
- Prickly moses (*Acacia pulchella*)
- Swishbush (*Viminaria juncea)*
- White myrtle (*Hypocalymma angustifolium*)

Sedges:
- Pale rush *(Juncus pallidus)*
- Jointleaf rush *(Juncus holoschoenus)*
- Finger rush (*Juncus subsecundus*)
- Knotted club rush (*Ficinia nodosa*)
- Nodding club rush *(Isolepis cernua)*
- Broad twig rush (*Baumea preissii*)
- River twig rush (*Baumea riparia*)
- Pithy sword sedge *(Lepidosperma longitudinale)*

Cross-section of the detailed design work done to improve the flow characteristics of the river for improved ecological value, and the native species list used for the project.

Source: Iluka Resources (2015).

The reconstructed streams were designed to improve species diversity at the site and were fenced off from cattle, unlike the pre-mine situation.

Reconstructed creek stabilised, showing stream rehabilitation circa 2008.

In addition to reconstructing the waterways, Iluka ran a riparian and farm tree belt vegetation planting program that focused on species that would provide adequate habitats for bird and aquatic life. The company's rehabilitation activities have resulted in the land being returned to highly productive dairy production. One farmer has converted 70 hectares of the previously mined land to a central pivot irrigation system for his dairy stock.

Reconstructed creek stabilised, showing stream rehabilitation circa 2014.

6.0 FINANCIAL ASSURANCE, PROVISIONING AND ENVIRONMENTAL LIABILITY

KEY MESSAGES

- Early recognition of mine closure costs promotes improved strategies for operations to plan additional mitigation strategies and anticipate progressive closure and rehabilitation activities.
- Processes for closure cost estimation reduce potential environmental liability, as they ensure investment; development and operating decisions made today are made in full recognition of the potential financial impacts of future closure.
- Under sustainable development principles, mining companies are required to consider mine closure planning and associated cost estimates across the LoM for financial reporting for provisioning purposes, regular reporting for environmental bonding and long-term LoM planning and budgeting.
- For LoM or asset planning purposes, organisations develop a closure cost estimate to be used for asset valuation, business planning and budgeting.
- Recognition of rehabilitation and closure costs promotes improved strategies for operations to plan additional mitigation strategies and anticipate progressive closure and reclamation activities.
- The use of risk management principles 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.

In the past, closure planning, costing and implementation across the mining industry were less than adequate. Many mining operations were abandoned by their owners and the resulting mine legacies were left to the regulators and community for management and clean-up. Poor performance by the industry provides a basis for NGOs and other community groups to pressure governments to impose significant final rehabilitation commitments on mining companies before and during the development and operation of mining projects.

Early recognition of closure costs promotes improved strategies for operations to plan additional mitigation strategies and anticipate progressive closure and rehabilitation activities. Closure planning and consideration of closure costs throughout the LoM can create shareholder value if the long-term closure liability can be reduced or eliminated during operations.

This section details three processes that can be used to estimate closure costs. The processes reduce the potential environmental liability, as they ensure that investment, development and operating decisions today are made in full recognition of the potential financial impacts for closure in the future.

6.1 Financial assurance and provisioning

Industry experience has shown that mine closure cost estimates vary over the LoM and generally increase significantly as the operation develops to maturity and finally to closure. This is mainly because of the increasing footprint and size of the mine, and because activities that will be necessary at closure are often not evident during normal operations and are therefore not included in closure cost estimates. This can be related to a lack of closure experience among operating personnel and knowledge gaps in planning, research and baseline data.

In recent times, as the industry has focused on protecting its social licence to operate, there has been a significant improvement in closure planning and implementation performance. This improvement has been strongly supported by the development of the ICMM Sustainable Development Framework and Principles (ICMM 2003) and the MCA Enduring Value Framework for Sustainable Development (MCA 2004). In addition, financial reporting obligations under International Financial Reporting Standards (IFRS) have led to better understanding and improvement of the industry's closure performance.

Under sustainable development principles, mining companies are required to consider mine closure planning and associated cost estimates across the LoM in three ways, according to their purpose: for financial reporting for provisioning purposes, for regulator reporting for environmental bonding, and for long-term LoM planning and budgeting.

6.1.1 Financial provisions

The industry's accounting obligation covering financial provision for mine closure generally aligns with public disclosure to support statutory accounting and reporting requirements as defined by the IFRS.

It is generally based on legal liability or compliance as a minimum, and represents an NPV estimation of the closure and rehabilitation costs of the current 'on the ground' disturbance footprint and decommissioning of the mine infrastructure at the time of reporting (usually annually) over the remaining LoM.

The financial provision liability estimates are required to legally comply with the regulations dictated by the generally accepted accounting principles of the reporting authority of the country in which the company operates, or as per the listing on the relevant country's securities and exchange commission (SEC) reporting requirements, or both. The estimate is filed with the relevant SEC as part of the company's annual financial report in line items including 'Other current liabilities', 'Environmental liabilities', 'Reclamation and remediation liabilities', and/or 'Asset retirement obligations'. It is meant to accurately represent an accounting estimate of the end of year 'on the ground' liability, appropriately discounted over the remaining LoM or life of the asset. Annual cash flows are used to calculate a single line item NPV of the liability in order to communicate this information to current and potential company shareholders through the annual report.

The financial provision cost estimate is generally lower than the LoM closure cost and the provision's estimated cash flow is adjusted to the Consumer Price Index and discounted at a pre-tax discount rate that reflects current market assessments of the time value of money and the risks specific to the liability over the remaining LoM to establish the NPV balance sheet provision amount.

6.1.2 Regulator financial assurance (environmental bonding and rehabilitation levies)

The financial assurance is the disclosure to the regulating authority to determine the quantum of a bank guarantee, insurance bond or cash required under a project's statutory obligation. This is generally calculated as per the regulating authority's guidance and is often based on third-party contractor rates for undertaking the closure works for the current disturbance footprint and the decommissioning of the mine infrastructure. In more recent times, some regulators (in Western Australia and the Northern Territory) are now requiring a levy to be paid based on the estimated cost to close the mine, with the funds of the levy to be used to address and rehabilitate legacy and abandoned mine sites in the relevant state or territory.

The financial assurance cost estimate is very similar in quantum to the financial provision estimate; this value is often calculated based on the regulating authority's own cost data. Those costs excluded from the financial provision estimate are also excluded from the financial assurance estimate.

6.1.3 Life of mine closure estimates

Typically, for LoM (or asset) planning purposes, organisations develop a closure cost estimate to be used for asset valuation, business planning and budgeting. It represents a 'best guess' estimation of the rehabilitation of the 'at end of mine' disturbance footprint and the decommissioning of the mine infrastructure. This final footprint is often much larger than what is expected due to continued development of the mine during its life; however, it can often be significantly reduced during operations through a well-managed progressive rehabilitation program.

As the mine moves nearer to closure, significant technical and environmental knowledge and detail are needed to ensure that all significant closure risks (and costs) are highlighted and addressed, and that appropriate decisions are made for the mine closure plan to be implemented effectively. The key value-add during the mining process, and hence the business case for early and continuous detailed closure planning, comes from incorporating strategic closure planning and environmental management decisions in the mine's operations planning. This provides the mine with the opportunity to maximise efficiencies in mine operations resources and material handling, minimise the disturbance footprint, and use valuable surface water and groundwater in an eco-efficient manner.

Early recognition of rehabilitation and closure costs promotes improved strategies for operations to plan additional mitigation strategies and anticipate progressive closure and reclamation activities. Closure planning creates shareholder value if the long-term cost liability can be reduced or eliminated during operations. A well-established closure planning process ensures that investment, development and operating decisions made today fully recognise the potential financial impacts for closure in the future.

Closure cost estimates are needed for various internal and external purposes. The key aspects that should be considered for the development of the estimates for provisioning, financial assurance and LoM planning are:

- the appropriateness of the rehabilitation and closure risks, strategies and activities to be costed within the models, and the issues associated with the differences in strategies between commitments, obligations and expectations of all stakeholders and the mining company's policies and standards
- the suitability and appropriateness of the cost modelling techniques, and the financial assurance and closure provision estimation processes adopted by the company
- the relevancy of the nominated investigations, studies and rehabilitation techniques and equipment required for the planned rehabilitation activities

- the adoption of appropriate cost and productivity inputs for the nominated rehabilitation strategy, equipment and other support activities (including the application of third-party contractor rates)
- the establishment of discrete land management units with similar geophysical and management characteristics, designated as domains or precincts (in addition to which there are elements of mine closure activities not confined to single domains, such as post-closure monitoring, water management, project management and contaminated land management)
- equipment mobilisation and demobilisation, contractor margins, management costs, training, survey, and support amenities and services.

Variations in the way that the liability estimates are calculated

LoM closure 'capital' raw cost estimate—used primarily for internal closure planning and LoM budgeting. This estimate includes existing and future disturbance, according to the current mine plan. It includes liabilities associated with any and all legal and non-legal obligations, project management costs, and post-closure monitoring and maintenance costs and is based on third-party contractor costs.

IFRS estimate—the IFRS estimate includes only the liability that exists at the balance sheet reporting date (31 December or 30 June). It the best estimate of the expenditure required to successfully close the site and rehabilitate the existing disturbance, meeting all closure objectives and criteria as required by policy objectives, legal obligations and agreements with stakeholders. This cost estimate is then discounted over the LoM plan to arrive at an NPV provision for reporting to the SEC in the company's annual financial accounts. It should be based on third-party contractor costs and should exclude the costs that are included in the LoM estimate (the salvage value for plant and equipment, inventory disposal costs, socioeconomic costs and contingency).

Financial assurance (security bond) estimate—this is required to be lodged with the presiding regulator as part of the mineral tenement licensing requirements. The amount of financial assurance to be lodged is calculated in accordance with relevant regulator guidelines, which generally require (Slight and Lacy 2015) that the estimate:

- be based on work being conducted by third-party contractors (rather than owner-miners)
- include the rehabilitation costs for each type of disturbance for each year of the plan (regulators usually require assurance for the maximum value within the plan life)
- include the cost of a contaminated site investigation that verifies that the licence conditions have been met
- include maintenance and monitoring costs for a period after closure.

Many other activities and studies must be undertaken during the operations phase of the mine to gain the knowledge, data and information to inform and develop the closure plan and subsequent LoM closure cost estimate. Those costs should be excluded from the LoM, financial provision and financial assurance closure cost estimates and must be included in annual operating budgets. They should account for closure planning staff and associated functional costs within the organisation (both corporate and onsite) as well as any technical, scientific and engineering studies done to establish the context and detailed requirements for the closure.

Scientific trials should be excluded from all of the closure cost estimates. Their costs should be included in operating budgets for specific trials to be done to test the proposed closure strategies for the relevant landforms, such as waste rock dumps and tailings storage facilities. As an example, waste landform or tailings cover trials should be considered as an operations cost and not be included in LoM, financial provision or financial assurance estimates. These operational costs may be eligible for research and development tax benefits and should be managed accordingly.

The goal of these trials is ultimately to demonstrate to the regulators and other stakeholders that the closure strategies selected for specific landforms will meet the desired closure objectives and, more importantly for the mine owner, will be more cost-effective, provide opportunity for innovation in reducing mine operating costs, and minimise long-term maintenance and management costs.

Some mine closure plans assume that the value of the assets at the closure of the mine that require decommissioning and removal from the mine site will offset the closure costs of those assets, which are considered cost neutral and not required to be investigated. Accounting standards, however, require companies to generate an assessment of the full decommissioning costs, with no value attributed to saleable or recycled assets or scrap considered in the evaluation. Those standards dictate that a liability cannot be offset by an asset value. In addition, it is good practice to develop comprehensive decommissioning management plans that include all the details required for the closure of all site infrastructure assets.

Case study: Australian Rehabilitation Liability Tool

The development of Anglo American's Rehabilitation Liability Tool

Anglo American's Metallurgical Coal Business Unit (Met Coal) operates open-cut and underground mines in Australia (Queensland and NSW) and Canada (British Columbia). All Australian mines are required by legislation to undertake progressive rehabilitation as well as to provide appropriate financial assurance provisions to 'satisfactorily' rehabilitate all mining-related disturbances.

All Met Coal operations have mine closure plans aligned with the Anglo American Group Mine Closure Toolbox (MCT). The MCT provides a structured approach to developing closure plans in which required detail is aligned with the remaining LoM and action plans are generated to close identified knowledge gaps. The MCT is available to be downloaded in English, Portuguese and Spanish at http://www.angloamerican.com/development/mine-closure-planning/mine-closure-toolbox.aspx.

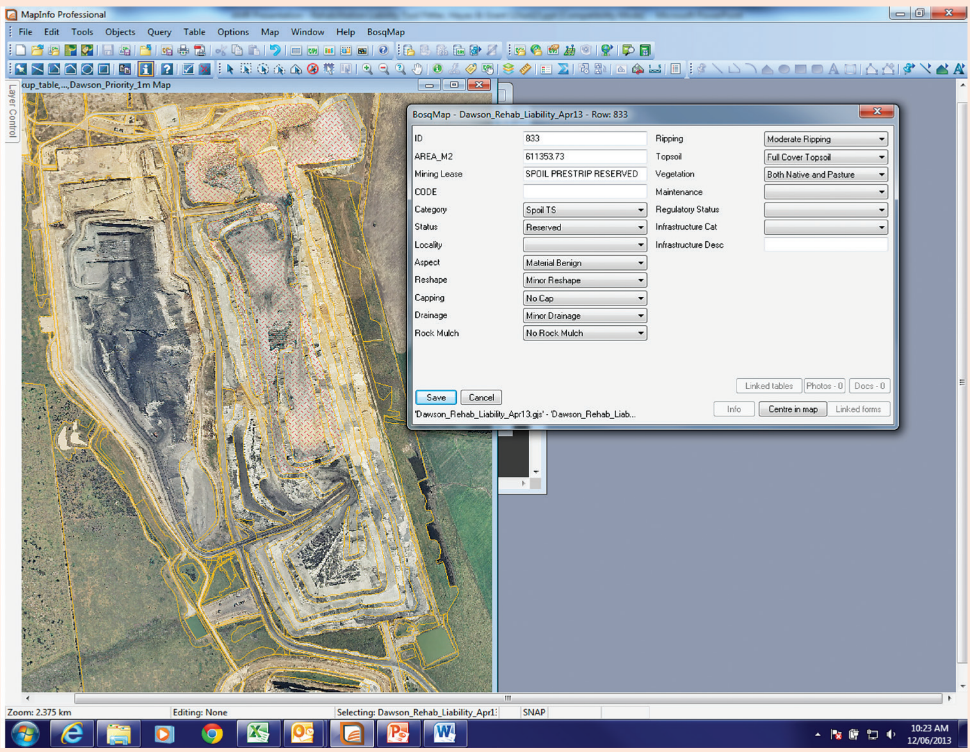
At Met Coal, mine planners and management have grappled with the perceived conflict between keeping mine areas available for potential future mining and the need to both complete progressive rehabilitation and manage financial assurances. Without an effective and reasonably accurate method of financially assessing environmental impacts, decision-makers usually implement mine plans with little practical appreciation of the underlying financial assurances.

A rehabilitation liability calculation tool was needed to more accurately calculate rehabilitation liabilities and the impacts that alternative mine planning options will have. Met Coal has developed a tool for Australian sites that uses MapInfo with a BosqMap software add-on and a customised Microsoft Excel spreadsheet template to calculate its rehabilitation liabilities.

The GIS mapping technology of MapInfo can be used to directly assess the impacts of mine plans in terms of both present and future rehabilitation liability. GIS-referenced aerial photographs are used to map present disturbance areas using one of 15 disturbance type 'domains'. A selection of up to eight generic treatments can be applied to each mapped disturbance type domain polygon, and a specific treatment can be assigned within each generic treatment selected (see first image). There are 80 commonly used domain and treatment prescriptions. Projected mine plans can be overlaid on the current disturbances to enable the visualisation and definition of forecast disturbances and changes. The exported disturbance areas, domains and treatments from MapInfo are used by a spreadsheet template to apply rehabilitation liability rates accepted by both the business and regulatory authorities.

Changes to rehabilitation liabilities as a result of the mine plan are clearly visible, tabulated, open to scrutiny and auditable. Mine processes, activities and plans have opportunities to minimise and reduce rehabilitation liabilities, as well as to increase them. Financially demonstrating the impacts of choices to decision-makers enables a more informed and balanced outcome to be determined and provides a strong incentive for mine planners to come to the table.

MapInfo software with BosqMap add-on using aerial photography to define mapping.



6.2 Minimise the potential environmental liability

As closure approaches, there is an opportunity to reduce the environmental liability by managing 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 include the following:

- Processing oxide material through the plant and sending it to tailings to create a benign layer, or cover, over more reactive tailings 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 the area of existing disturbance.
- When undertaking the inventory of sites to be rehabilitated, each stockpile of rock, tailings or leached material (in the case of precious metals) may be assessed to ascertain for its potential value. After confirmation that the material will not be processed and does not require specific treatment, it can be assessed 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 in which a waste material may be used to mitigate a risk factor on another waste pile, such as by using a pile of coarse durable waste rock to rock-armour another pile of proven erodible soils. Durable rock can also be seen as a valuable resource by local stakeholders such as shire councils for road construction works, provided it is chemically benign.
- Placing 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 constructing 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 needed to capture and treat poor-quality effluent for many years.

The use of risk management principles 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.

Case study: Closure, stakeholder engagement and environmental values

The Beenup mine site is in south-west Western Australia, near the confluence of the Blackwood and Scott rivers on the Scott coastal plain. Land in the area is used mainly for beef and dairy pastures, 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 when the predicted settling and consolidation rates for the fine clays were not 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 had been disturbed. Most of the disturbance was associated with the dredge pond and above-ground storage facilities.

One of the initial steps taken 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 that end, the company set out to develop a flexible plan that 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) comprised shire representatives, landowners, and business and conservation group representatives.

To assist the community's 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 began the 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 the government to obtain feedback on aspects of the plan.

The key issues identified were:

- the quality of water released from the site
- the security of acid soils
- impacts on groundwater and surface water
- long-term rehabilitation of the mine development storage area

- impacts on the hydrological regime
- the rehabilitation of trial mine areas
- the landscaping and land use of the area.

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

In 2001, the BCG set up an independent audit of progress against the rehabilitation plan based on a protocol that it had developed. This process facilitated continuous improvement and gave the local community and the company the opportunity to ensure the 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 the completion of the earthworks and revegetation activities, both the government and the community maintain confidence and ownership in the progress of the rehabilitation project. Community members are now very familiar with the principles of sustainability and speak with some authority on the subject.

The keys to the success of the Beenup closure project were:

- 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 BCG
- detailed disclosure and understanding between the company and community
- the implementation of an independent community-directed rehabilitation audit
- the use of well-recognised consulting firms for technical direction.

June 1999

November 2002

Source: *Mine closure and completion* handbook (2002, 2006).

7.0 DECOMMISSIONING AND CLOSURE

KEY MESSAGES

- Leading practice in mine closure planning includes the requirement to develop in detail relevant and specific decommissioning management plans for all closure activities.
- A decommissioning plan should be developed to guide activities at the end of the mine operations and detail the resources that will be needed to undertake those activities.
- The objectives of the plan include describing the process for undertaking the closure activities, complying with all legal obligations and communicating to minimise the risk of safety and environmental incidents.
- The plan should outline how all the infrastructure remaining at the end of the LoM is to be managed and financed into the future, and provide opportunity for the community and other stakeholders to provide input.
- Valuing assets and completing a detailed itemised inventory is a significant task for most mines and should be started several years before closure or, ideally, as part of business as usual.
- Understanding and predicting the likely environmental conditions that will develop after closure assist in quantifying completion criteria and reaching agreement between the mine operation and regulators on the environmental requirements that must be met to allow the mining permit to be relinquished.

Leading practice in mine closure planning includes the requirement to develop in detail relevant and specific decommissioning management plans for all closure activities. Closure planning will highlight many activities requiring decommissioning plans, including for the closure of landforms; the decommissioning and demolition of site infrastructure; the rehabilitation of all disturbance footprints across the project; post-closure monitoring; and ultimately the final relinquishment of the mineral tenements. Those decommissioning plans should be developed to guide activities at the end of the mine operations as a part of a planned mine closure strategy and, more importantly, provide detail of the resources that will be needed for those activities. The decommissioning plans should be reviewed and updated where required and specifically within two years of mine closure.

The objectives of decommissioning plans are to:

- describe the process for undertaking the closure activities, including for waste rock landforms and TSFs, and clean-up, decommissioning and demolishing the mine site infrastructure as a part of the closure plan
- comply with any and all legal obligations regarding decommissioning and rehabilitation activities
- communicate the mine owner's approach to managing the site during the closure, decommissioning and rehabilitation phase
- minimise the risk of safety and environmental incidents during the decommissioning phase.

Decommissioning planning will require support and input from many of the site's personnel, including the management team and staff in the ore processing, environmental, community relations, human resources, safety, mine planning, engineering and project management areas.

As discussed elsewhere in this handbook, most mines typically divide the site into a number of domains. A decommissioning plan needs to show the activities and tasks to be undertaken step by step and the resources required to do the job (equipment, people, management and supervision, and contracted resources). The plan needs to consider other essential services, such as power, water and maintenance workshop availability, as their removal could affect proposed decommissioning schedules. In some instances, portable generators and mobile workshops will need to be hired as key infrastructure is removed, and power will still be needed for maintenance and decommissioning equipment.

7.1 Developing a decommissioning plan

To prepare a decommissioning plan, suitable civil engineering decommissioning experts or cost estimators should be engaged to advise on the most 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.

A decommissioning plan should outline how all the infrastructure (such as plant, buildings, bitumen roads, conveyors, power systems and so on) remaining at the end of the LoM is to be managed into the future. This may involve leaving some infrastructure for use by a third party, selling assets, demolition, recycling or reuse (these components are covered in the following sections), and the final rehabilitation and monitoring of the disturbed area.

The sequence of decommissioning 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 semi-autogenous grinding (SAG) and ball mills and haul trucks, although this usually becomes the responsibility of the purchaser if the operation is sold.

Decommissioning will generate considerable waste material, the volume of which often exceeds preliminary estimates. The need to decontaminate hazardous chemicals used during the process should be identified, and a decontamination and disposal process established. Steel and other recyclables will be able to be removed offsite and usually sold for a profit (depending on distance to market); however, other wastes will need to be disposed of in an appropriate registered landfill. The ability to dispose of material by onsite burial will depend on the nature of the waste and the post-mining land use of the rehabilitated area.

The decommissioning plan should ensure that exit strategies are in place for all community development programs (MCA 2004: Enduring Value element 9.3), and that there is an opportunity for the community and other stakeholders to provide input. Opportunities may exist with local communities to reuse and recycle some of the materials and, if that is appropriate, a disposal plan that incurs no risk or liability on the company will need to be developed. This will ensure that the material is removed from the mine safely and distributed equitably among community groups.

Critical to the success of mine closure will be the management of staff and employees. As a mine approaches closure, there is usually 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 during the decommissioning and closure phase. It is critical to establish the skills that need to be retained in order to complete the decommissioning and closure tasks. The key people who need to be retained are those with the necessary competencies and who can embrace change, as every day will present a different working environment. 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 individual decommissioning activities need to be completed on an ongoing basis and working procedures actively developed and implemented to ensure that tasks are completed safely. Maintaining a strong, active safety culture is vital, as decommissioning and closure result in a constantly changing, high-risk workplace environment.

Case study: Mt McClure gold project, Western Australia

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

Located in the Northern Goldfields, 80 km north-east of Leinster in 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 TSFs.

In planning for the full decommissioning of the project, the closure management team ran a risk assessment using 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.

Benchmarking tours were a significant innovation. These tours—for personnel in the closure team, including bulldozer drivers, earthworks contractors and consultants—involved visiting numerous closed and abandoned mines within a 500-km radius of the operation. The visits provided valuable information about the design of an optimal closure plan.

Addressing the ‘people’ issues related to mine closure can involve a surprising number of different groups. Successful mine closure can occur only when all the people involved 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 found 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
- contractors
- consultants
- universities
- owners (as a corporate entity)
- operational-level personnel
- members of the wider closure project team dealing with human resources, safety, and care and maintenance.

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 than usual 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 operation 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' at Mt McClure.

Mt McClure mine site.

Further details of this case study are available in Lacy and Haymont (2006).

Source: *Mine closure and completion* handbook (2006).

7.2 Valuing assets and planning for their sale or transfer

Before assets can be sold, they need to be valued and a detailed itemised inventory completed. This is a significant task for most mines and ideally should be part of business as usual, or at least started several years before closure. Preliminary work should commence using the asset register; however, asset registers are sometimes 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.

Three main types of approach are used to sell mining assets: sale by prior agreement, usually through a tender arrangement or equipment broker; sale through advertisements; and public auction. An experienced equipment sales broker and auctioneer are usually engaged to act on the company's behalf to sell all plant, buildings and equipment on a commission fee contract. Expected returns for well-maintained plant and mobile equipment are 10–20% of the new price.

Planning for mine closure can help to mitigate 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. For example, demountable buildings, furniture, equipment, fencing or a water borefield may be highly valued by local government or the local community.

The community or local council may also ask that access roads and airstrips not be removed. The future use of mining infrastructure by a third party is often an attractive option to all parties. However, significant challenges often occur in getting agreement from the various regulators and striking an agreement with a third party for the long-term management of the asset. This is best managed by starting negotiations with third parties as soon as possible. This will require negotiation and planning to ensure that there is a clear transfer of assets or infrastructure that does not impose any further liabilities for the company.

7.3 Decommissioning infrastructure and pollution/contamination and remediation

Before closure, the site management should have a clear understanding of the types and extent of any soil and water contamination present. Understanding and predicting what environmental conditions will develop after closure (pit lakes, groundwater conditions, tailings consolidation) are all part of knowledge gap reduction. At this stage in the closure planning cycle, the mine operators and regulators should agree on what environmental requirements must be met to allow the mining permit to be relinquished.

With proper planning, the mine operation should have made provision for or built the required infrastructure to remediate the specific contamination in advance of physical site closure. That infrastructure could include passive or active AMD mitigation systems, water treatment plants, conveyance pipelines, tanks, soil repositories and remediation areas and, if required, wetland filters. This is a prudent strategy, given that unplanned closure can occur and the exact time of closure is unpredictable.

When planning infrastructure requirements at closure, it is important to understand the length of time needed to achieve the required clean-up standards. In many cases, water treatment plants, passive drainage systems and lime repositories may be operational for decades. Capital needs to be provided for management, maintenance and, in some cases, fixed plant replacement costs. It is necessary that the completion criteria to be met are firmly and clearly established with key stakeholders. If remediation standards or requirements are changed during this period, the company could be exposed to conditions that may be unobtainable for a number of reasons, thus leaving a site in a state of unforeseen perpetuity management.

7.4 Legacy infrastructure

Legacy infrastructure left behind as a result of the mining activities can include TSFs, waste rock landforms, open voids, pit lakes and other sources of potential pollution. Less visible infrastructure can include groundwater capture systems, soil or synthetic caps, passive or reactive barrier walls, decline and shaft entrances, and reclaimed areas.

An issue with legacy infrastructure is how industry ensures that it is sustainable into the future. Seepage from TSFs and waste rock landforms often takes time to develop, and sometimes revegetation plots fail to achieve the desired coverage. Therefore, it is important to establish proper monitoring and action plans that encompass the legacy infrastructure so that it remains fit for purpose. Equally important is to determine who will manage the infrastructure into the future: will the site be managed by a third-party service provider, and are they competent to provide the care and maintenance required?

Financial provisions may need to be established to accommodate monitoring and maintenance costs for legacy infrastructure. Those costs can be reduced if the site management is proactive in cleaning up known contaminated sites before closure and any reclamation work is designed and built to a higher standard to avoid rework sometime in the future.

8.0 MINE RELINQUISHMENT

KEY MESSAGES

- The final milestone in the LoM arrives when decommissioning, closure, rehabilitation and post-closure activities are complete. At that point, regulatory approval is sought for the relinquishment of the mining lease.
- The relinquishment process normally involves a final evaluation of the site to ensure that it has met all the designated performance and completion criteria.
- Formal closure, sign-off and relinquishment mechanisms with the lead regulatory agency should be established to outline the responsibilities, accountabilities and proposed methodologies needed to achieve successful sign-off.
- The company should aim to mitigate the adverse environmental and social impacts of the mining operation in order to minimise its residual risk, which ultimately enables it to relinquish responsibility for the site's management.
- After mine closure, some rehabilitated mined land may require ongoing management and monitoring before lease relinquishment. Workable solutions and a timeline to achieve relinquishment are some of the processes and issues that need to be discussed with the regulators and stakeholders.
- After relinquishment, the company has no further obligations under the mining lease or other approval, but may still have some responsibilities for the site if it is the landholder.
- The industry recognises that to gain access to future resources it needs to demonstrate that it can effectively manage and close mines with the support of the communities in which it operates.
- The future of the mining industry is dependent on the legacy it leaves.

The final milestone in a mine's life occurs when decommissioning, closure, rehabilitation and post-closure activities are complete. At that point, regulatory approval is sought and the mining lease relinquished.

The company should aim to mitigate the adverse environmental and social impacts of the mining operation in order to minimise its residual risk, which ultimately enables it to relinquish responsibility for the site's management.

The relinquishment of a mining lease can only happen when the resource that can be profitably mined has been exhausted and all the completion criteria established for the mine are met. After relinquishment, the company has no further obligations under its mining lease or other approval, but may still have some responsibilities for the site if it is the landholder.

8.1 Mine lease relinquishment

Mining approvals and tenement conditions are typically framed with an expectation that rehabilitation will return the site to a condition that will allow the lease to be relinquished, with all obligations for future maintenance and monitoring discharged and control of the site returned to the state. However, there are relatively few examples of successful lease relinquishment in Australia, and the industry and regulators are becoming aware of just how challenging it is for mining companies to meet the agreed post-mining land-use and completion criteria.

It is clear that a well-run mine (with carefully considered planning for closure from the outset, and using leading practice techniques to reduce the potential for AMD, for example) will minimise its management's difficulties at the time of closure, and the time it will take to satisfy regulators and stakeholders that the lease can be relinquished.

At some point after mine closure, successful rehabilitation and implementation of the closure plan, 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 for relinquishment, and those should be reviewed and followed. There is often a need to take 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 normally involves a final evaluation of the site to ensure that it has met all the designated performance and outcome criteria. This may involve a third-party assessor or a panel of experts or stakeholders who can perform 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 involved and advise on whether the company has met all the community closure concerns raised throughout the duration of the project. This process highlights the need to ensure that mine closure criteria are drafted carefully to make them both measurable and achievable to allow for successful relinquishment.

Case study: Kestrel progressive rehabilitation certification

Kestrel Coal Pty Ltd achieved the first sign-off under the progressive rehabilitation provisions of the Queensland *Environmental Protection Act* 1994 in February 2014. The sign-off relates to 570 hectares of land over previously mined 200 series longwall panels.

The Kestrel Mine is about 50 km north-east of Emerald on the Central Highlands and is operated by Rio Tinto Coal Australia Pty Limited's (RTCA) subsidiary, Kestrel Coal Pty Limited. The land is owned freehold by Rio Tinto and leased to the North Australian Pastoral Company (NAPCO) for grazing and the cultivation of forage crops. Mining in this underground mine ceased in late 2003 and was followed up immediately with rehabilitation initiatives, which were completed in 2006. In 2010, Rio Tinto applied for certification of a significant portion of the longwall series as rehabilitated land, totalling around 570 hectares.

Prior to mining, the longwall area formed a gentle rolling landscape. Slopes were generally less than 5% and drained to ephemeral streams. During the operation of the mine, a subsidence trough 1.5 to 2 metres deep formed over the width of each longwall.

Progressive rehabilitation certification

The Environmental Protection Act is the legislative framework for rehabilitation in Queensland and provides for the certification of progressive rehabilitation, which in effect means that the land has been rehabilitated under all the relevant requirements of the Act, the environmental authority under which the resource project is authorised and any other relevant guidance that is made under the Act. The area the subject of the progressive certification is then considered to be a 'certified rehabilitation area' for the relevant tenure. In this particular case, the requirement was to reinstate a 'good quality agricultural land' capability. Should rehabilitation requirements change during the life of the mining operation, no retrospective conditions can be placed on certified rehabilitation areas.

The RTCA approach

RTCA decided in 2009 to apply for progressive certification for the completed longwall mining area. As required under the Act, a progressive rehabilitation report was compiled. It included monitoring data that had been recorded before, during and after the mining, including

- a review of all available baseline data and pre-mining information (RTCA did not begin the original mining operations, but acquired the mine in 1999)
- subsidence monitoring / land stability data, which included satellite imagery and targeted field work over a number of years (including data from two ACARP projects)
- an independent land capability class assessment, which compared results against baseline information and defined environmental authority requirements
- observations from the lessee (NAPCO), which had been managing the land since 2003.

In accordance with the Act requirements and guidance, the progressive rehabilitation report included an independent audit/review of the report and a residual risk assessment. The rehabilitation conditions within the site environmental authority (EA) were used to determine the completion criteria.

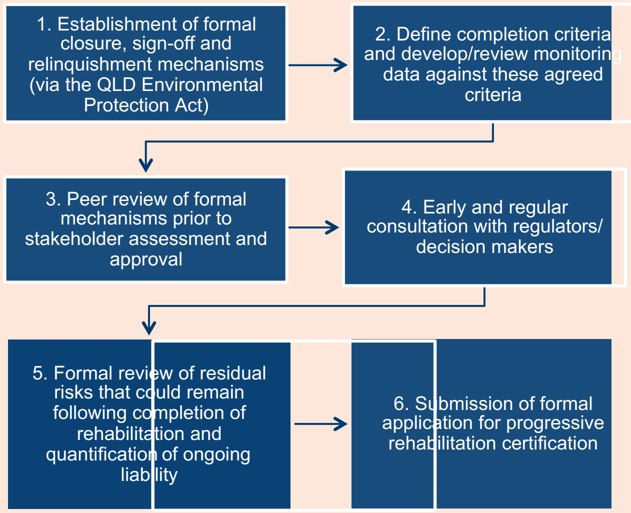
Consultation with regulators

RTCA commenced consultation with the regulator (now the Department of Environment and Heritage Protection) early in the process.

As this was the first formal application for progressive rehabilitation certification in Queensland, there were a number of delays in the process as the department consulted on how to progress the application. Additional information requests were received, including for further clarification on potential hydrological impacts.

Following extensive consultation and a site visit by departmental staff, the formal sign-off was received (via a decision notice) in March 2012.

The key steps are summarised in the following flowchart.



Rio Tinto has now set the benchmark for rehabilitation to an agreed standard. Progressive rehabilitation certification of the 200 longwall series demonstrates that mining can coexist with other land uses and that the land can be returned to a suitable state after mining.

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

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

The mine operator should establish working arrangements with the lead regulatory agency that outline the responsibilities, 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 post-mining land-use and completion criteria addressing environmental, social and economic outcomes
- monitoring and reporting requirements
- self-assessment against the completion criteria as a precursor to the operator presenting close-out areas for handover
- a process for dealing with areas that fail to meet completion criteria, including corrective action
- an agreed record-keeping process for sites proposed for close-out
- the establishment of a formal close-out audit process with the regulatory agency or a third party for the handover areas.

2. Peer review of formal mechanisms before stakeholder assessment and approval

Peer review of the completion 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 or checklist in consultation with stakeholders that is applicable to each rehabilitated area presented for sign-off.

The completed checklist is a record of the status of the rehabilitated area against the completion criteria and any other agreements made between the parties relating to the area in question. It will need the signatures 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 (or appropriate regulator) that details those areas that have been signed off and for which the lease has been relinquished. The letter should advise the operator that the relevant state or territory government has accepted responsibility for the rehabilitated lease.

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

Areas that do not meet completion criteria will be identified in an agreement with the regulatory agency and a corrective action plan will developed to meet the criteria. The plan will detail remedial works needed to address the concerns 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 a trust fund or other financial arrangement that will generate income for the ongoing management of rehabilitated areas, if this mechanism provides a means for early sign-off and handover to government.

8.2 Post-closure management requirements

After mine closure, some rehabilitated mined land may require ongoing management and monitoring before lease relinquishment. These processes and issues need to be discussed with the regulator and workable solutions and a timeline considered along with post-closure management and monitoring, and finalised over time in order to receive sign-off by the regulator and stakeholders.

Responsibility for management following mine decommissioning and closure through to lease relinquishment depends on what is needed to reach post-mining land-use agreements. The new land users are then responsible for managing the land and any legal aspects.

Typically, post-closure 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.

Funding post-closure management and monitoring that will be required as a normal part of the LoM is discussed in Section 6.1. Much of this planning is determined by the mining lease holder, in consultation and communication with the regulatory authorities and stakeholders.

Funding for any required post-relinquishment management and monitoring 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 the objective of mining companies that they be absolved of any ongoing financial liability and there will be no long-term financial burden on government or society. For example, in Queensland, the Environmental Protection Agency 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. The bonds would be held and funds drawn down to remediate potential areas of failure (QEPA 2006).

Risks associated with post-closure and the relinquishment phases in the LoM cover both economic and non-economic consequence types and are long term. The expectations of the local community, government, landowners, neighbouring property owners and NGOs need to be taken into account. A well-planned and managed closure process will protect the community from unintended consequences well after the mining company has left the district and will protect the reputation of the mining industry.

Closure strategies for some mine operations may include initiatives to create enduring legacies that enhance social and/or environmental values in the vicinity of the mine and in surrounding communities. In this way, the reputation of the mining company and the industry will be enhanced.

Case study: Large-scale, long-term multiple facility mine closure at Tanami Mine Joint Venture, Northern Territory

This case study highlights the sustained effort of a closure team with a well-defined, well-resourced management structure to create a high-quality closure process under challenging circumstances.

The Tanami Mine is on Aboriginal freehold land in the Tanami Desert in the Northern Territory, about 670 km west of Alice Springs—a very remote and inhospitable area. The area was mined and processed for gold from 1900 to 2004. The site comprised 45 open pits, 8 backfilled pits, 11 in-pit TSFs, 24 waste rock landforms, 2 above-ground TSFs, a processing plant and onsite village accommodation. It went into a mine closure program from 2005 to 2010. After a period of closure planning, investigation work and sustained and large-scale earthworks over five years, Tanami Mine Joint Venture (TMJV) (Newmont Mining) sold the closed mine on to the next potential operator, Tanami Gold.

The final land-use objective for the Tanami Mine is for rehabilitation of the mined environment to return to the values of the surrounding ecosystems. Following demonstration of rehabilitation and achievement of lease relinquishment, eventually the area will be returned to the site's traditional owners for traditional use. Consultation with key stakeholders facilitated a transparent closure process.

The harsh environmental conditions, the size of the site and the array of landforms, some composed of highly unstable and dispersive waste material, further complicated the closure process.

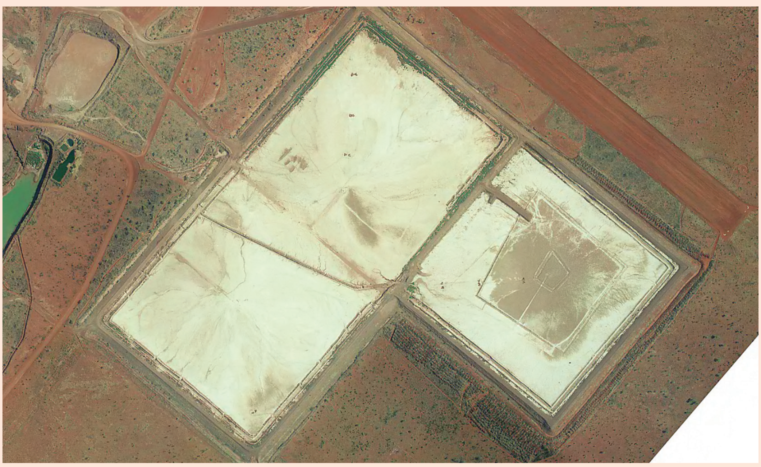
A closure project team bears some resemblance to a construction team. The members are involved for a relatively short term, they need to be focused on safety, quality and costs, and they are operating when some of the usual support staff and infrastructure of a mine site have been reduced or disappeared (Lacy and Haymont 2006). They have the opportunity to influence the closure and rehabilitation process in many ways, and a range of skills and knowledge is required.

Haymont et al. (2008) proposed that questions such as those below should be asked of team members and the team management before beginning any large, challenging closure project:

- Are the people selected to be involved in the project experienced in the specific field of rehabilitation and closure?
- Have the leaders led well before, and will the team accept that leadership and, where necessary, challenge it?
- Is the team to be supported and well resourced?
- Are the types of people in the team able to provide feedback, accept and deliver constructive criticism and make observations at all levels?
- Are they familiar with the physical and climatic environment they are in and its various cycles and events?
- Are they the types of people who will collaborate and contribute across disciplines or focus only on their own?
- Will they care about what they do?
- Have they the capacity to respond to new information or emerging patterns (the capacity to demonstrate adaptive management)?

The successful progress of the Tanami mine closure works program was largely the result of effective interaction between an experienced closure and reclamation team and a committed and engaged workforce. The management team provided leadership in planning, design, execution, environment, safety, community relations and cost control to assist and engage the workforce.

The following images show an area of the mine before and after rehabilitation.



Three Cell TSF 2003—before rehabilitation.

Three Cell TSF 2013—after 2008–09 rehabilitation. (Google Earth)

Further details of this case study are available in Lacy and Haymont (2006), Potts and Lacy (2008) and Haymont et al. (2008).

9.0 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 understands that it is required to ensure that comprehensive mine closure is done within the broader context of social and economic equity and sustainable development.

This handbook introduces a number of aspects that are intrinsically linked to closure, including legal and regulatory requirements; cumulative impacts; impacts on local and regional biodiversity, climate change, post-mine land use opportunities, the physical, chemical and geochemical characterisation of soils and mine wastes; and engineered landform design. Interaction and consultation with the community are considered integral throughout the handbook. The relationship of these aspects throughout the seven phases of the mining cycle, including post-closure management, is discussed as a site moves towards post-mining land use and relinquishment.

This handbook introduces the mineral resource legacy framework (Figure 1) for general discussion on the issue of legacy and the cyclical nature of mining and subsequent responsibilities. The interrelationship in the discovery and utilisation of minerals involving mining, communities and government is represented simply in the framework.

Planned mine closure and relinquishment are still at the early stage of implementation in Australia. There are limited examples of mine closure planning being applied from conception through to relinquishment. This is largely due to the time frame of most mining operations and the relatively recent development of integrated mine closure planning. However, in this handbook the mining industry showcases some of the excellent work done by the industry and the minerals sector in applying the principles of leading practice mine closure.

This handbook also stresses that the following essential elements are needed to achieve mine closure and relinquishment:

- Recognise and address the closure issues that the mining operation needs to consider in its *planning for closure* through to relinquishment.
- Developing a *risk management approach* to mine closure planning that applies from mine concept to post-closure and is integrated with whole-life of-mine planning.
- Perform the *closure activities* associated with each step in the LoM cycle and integrate them into business practice via the progressive implementation of a closure system.
- Understand the *processes and tools* that can assist the mining operation to achieve leading practice in mine closure and relinquishment.
- Understand the need for *engagement with communities and regulators* in establishing and implementing leading practice closure, as the community inherits the resource legacy.
- Collect *quality baseline data* and develop a *high-quality knowledge base* that is easily accessible.
- Develop *closure objectives and completion criteria* in the planning phase of the mine, in consultation with key stakeholders, and then regularly review them as research, monitoring and progressive rehabilitation is undertaken.

- Recognise that the physical, chemical and geochemical characterisation of soils and mine waste is an important component of engineered landform design and construction.
- Recognise that mine tailings rehabilitation and closure requires a unique focus.
- Recognise that water management and its interaction with the mine landforms is a critical closure element.
- Consider mine closure planning and associated *financial provisioning* across all phases of the LoM, developing estimates for provisioning, regulatory reporting and long-term LoM planning and budgeting.
- Be aware that the *pre-decommissioning and closure planning stage* is critical and requires a focus on liability, planning, assets, divestment, remediation, legacy infrastructure and post-closure monitoring and management.
- Use *advanced and careful planning* to ensure that the transition to post-mining land use and relinquishment is as smooth as possible.

This handbook emphasises the need for mining to focus on developing closure objectives and completion criteria that are based on the post-mining land use as the goal of mine closure. It encourages systematised closure planning, as unplanned closures are not cost-effective and often result in substandard rehabilitation. Early recognition of rehabilitation and closure costs promotes improved strategies for operations to plan additional mitigation strategies and anticipate progressive closure and reclamation activities.

Mine closure and rehabilitation ultimately determine the legacy that is left behind as a post-closure land use for future generations. If mine closure and rehabilitation are not undertaken in a planned and effective manner, throughout the LoM, a site may continue to be hazardous and a source of pollution for many years to come. The overall objective of mine closure and relinquishment 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.

The key value gained and hence the business case for early and detailed closure planning comes from incorporating strategic closure planning and environmental management decisions into mine operations planning. This gives the mine the opportunity to maximise efficiencies in the allocation of operational resources and materials handling, minimise disturbance footprints, and use valuable surface water and groundwater in an eco-efficient manner.

Assigned as a high priority by all levels of management, the integration of the closure elements outlined in this handbook into day-to-day operations will allow the mine to reach a state where mining lease ownership can be relinquished and responsibility can be accepted by the next land user. To achieve this in an environment of increasing regulatory and stakeholder expectations requires leading practice developed and implemented in consultation with local stakeholders. Not only will the implementation of progressive rehabilitation and systemised closure result in achieving the post-mining land use and a more satisfactory social and environmental outcome; it will, most importantly, sustain and enhance the standing of the mining industry.

APPENDIX 1: ENDURING VALUE: OVERVIEW OF KEY PRINCIPLES AND ELEMENTS

In 2012, the Minerals Council of Australia revised the 10 principles expressed in its minerals industry framework for sustainable development. The revised draft principles and elements pertaining to closure follow.

Key principles and elements related to mine closure

Principle 2: Integrate sustainable development considerations within the corporate decision-making process

- Plan, design, operate and close operations in a manner that enhances sustainable development (element 2.2).

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.
- 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.

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 7: Contribute to conservation of biodiversity and integrated approaches to land use planning

- Support the development and implementation of scientifically sound, inclusive and transparent procedures for integrated approaches to land use planning, biodiversity conservation and mining (element 7.3).

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

- Engage with and respond to stakeholders through open participation and consultation processes (element 10.3).

APPENDIX 2: ISSUES, CONSEQUENCES AND OPTIONS FOR REDUCING IMPACTS

Underground voids and shafts

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Stope failure or void collapse • Surface subsidence	• Backfill upper levels with waste rock or paste (during operation)
Planned surface subsidence • Surface water impacts	• Integrate subsided landform • River diversion
Acid rock drainage and hydrocarbon pollution • Adverse groundwater quality	• Recover watertable (flooding of underground) • Treat and replace acidic water, sulphide-reducing bacteria • Segregate known aquifers (operational) • Cement and seal adits
Public safety • Human injury or death	• 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)
Fauna • Injury or death • Loss of habitat	• Fauna survey • Creation of habitat (bats) • Prevent access (see above)
Post-mining land uses	• Stakeholder engagement to identify community preferences • Research • Tourism • Waste disposal • Bioreactors (methane production) • Water supply.

Open-pit pits

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Acid rock drainage and leachate production from exposed walls • Poor groundwater quality	• Backfill above predicted recovered groundwater level • Maintain water quality during mining • Treat water (lime) • Seal potential acid rock drainage generating surfaces. • Refill pit with water (such as stream diversion and/or groundwater recovery)
Void stability • Slumping • Wall failures	• Bench highwall and reshape low wall to a stable slope angle • Batter or blast high wall to safe and stable angle • Backfill to support internal walls
Public and fauna safety • Injury or death	• Hostile materials may need immediate covering (such as possible spontaneous combustion) • Barrier to discourage human access • Abandonment bunds of competent rock (where possible) and located outside of area of wall instability • Fencing and signage
Aesthetics • High visual impact • Industry reputation • Negative public reaction	• Stakeholder engagement to identify community view • Revegetate void surroundings • Screening • Create wetlands • Backfill or collapse and revegetate berms

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Post-mining land use	• Stakeholder engagement to determine possible uses • Aquaculture • Recreational facilities • Educational areas • Water storage • Domestic and/or hazardous waste disposal
Long-term viability of rehabilitation	•If infilled—weed control and revegetation.

Tailings storage facilities

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Erosion and structural instability • Overtopping from floodwaters • High phreatic surfaces • Piping of materials during seepage • Sedimentation • Surface flooding erosion of batters	• Geotechnical review/risk assessment on closure • Integrity from construction phase • High quality operational management • Rock armouring • Buttressing • Drainage control • Erosion resistant cover • Integration of cover into surrounding environment
Acid rock drainage • Internal and external instability • Water impacts • Acid soil • Toxic to biotic systems • Gas and thermal emissions • Cover deterioration and failure	• Geochemical characterisation and selective discharge • Cover and capping research studies and design to reduce water and oxygen reactions • Identification of cover material source and availability • Monitoring of cover performance and integrity • Store and release cover systems • Use as waste backfill in open pits or underground • Neutralisation (lime) and treatment (sulphide-reducing bacteria) • Segregation/isolation/encapsulation • Passive leachate management and treatment
Dust • Visual impact • Offsite pollution effects • Flora and fauna	• Surface capping to prevent wind erosion (such as rough cover, rock mulching) • Wet cover/wetlands • Revegetation • Wind breaks • Hydromulch • Stakeholder engagement to inform of plans to address issues
Groundwater • Aquifer contamination • Limitation of beneficial use • Recharge impact • Localised mounding	• Reduce hydraulic head by water shedding • Integrate capture release systems • Utilise evapotranspiration • Cap and cover with capillary break • Drainage diversions • Neutralisation and detoxification of tails seepage • Wetland filtration
Aesthetics • High visual impact • Industry reputation • Negative public reaction	• Effective landform and cover design • Revegetate surface
Public and fauna safety • Injury or death	• Stakeholder engagement to inform development of action plans to address public concerns • Effective landform and cover design • Restrict access
Long-term viability of rehabilitation • Injury or death	• Stock and feral animal control • Monitoring • Weed control.

Waste rock landforms

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Erosion/instability • Safety • Sedimentation • Slope/piping failure	• Signage and isolation bunding • Revegetation/rehabilitation • Landform design appropriate to materials used • Surface water management (stream diversion)
Surface water • Sediment loading • Contaminated water • Visual impacts • Interruption of water courses	• Placement of erosion control measures • Drainage control • Erosion resistant outer covers • Material characterisation • Wetland filters • Containment • Revegetation
Groundwater • Aquifer contamination • Limitation of beneficial use • Recharge impact • Localised mounding	• Waste characterisation including geochemistry • Selective placement of covers and caps • Location relative to landform and substrate • Hydrogeology studies prior to placement
Acid rock drainage • Internal and external instability • Water impacts • Acid soil • Toxic to biotic systems • Gas and thermal emissions • Cover deterioration and failure	• Geochemical characterisation and waste selection placement • Cover and capping research studies and design to reduce water and oxygen reactions • Identification of cover material sources and availability • Monitoring of cover performance and integrity • Store and release cover systems • Use as waste backfill in open pits or underground • Neutralisation (lime) and treatment (sulphide-reducing bacteria) • Segregation/isolation/encapsulation • Passive leachate management and treatment
Dust • Visual impact • Offsite pollution effects • Flora and fauna	• Stakeholder engagement to inform of plans to address issues • Surface capping to prevent wind erosion (such as rough cover, rock mulching) • Wet cover/wetlands • Revegetation • Wind breaks • Hydromulch
Aesthetics • High visual impact • Industry reputation • Negative public reaction	• Stakeholder engagement to inform development of action plans to address public concerns • Effective landform and cover design • Modelled to complement surrounding landforms • Revegetated
Post-mining land use • Loss of economic benefit	• Stakeholder engagement to determine uses • Tourism • Farming/horticulture • Recreation • Stored resource.

Treatment plant, office buildings and maintenance facilities

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Salt, heavy metals and hydrocarbons • Contaminated soil • Contaminated water	• Removal • Bioremediation • Treatment • Isolation and encapsulation
Buildings/infrastructure • Safety • Pollution	• Stakeholder benefits • Asset register • Community or tourist facility • Re-sell
Services	• Recycling • Asset register
Concrete • Soil pollutione	• Removal/bury • Recycling
Drainage • Contaminated runoff	• Reinstate/modification, divert • Sediment traps
Pre/post-mining heritage	• Stakeholder engagement • Tourism
Compaction • Restricted revegetation	• Deep ripping.

Mine townships

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Social dislocation • Unemployment	• Stakeholder engagement • Counselling/retraining/placement • Relocation
Regional economic loss • Small business collapse	• Seed capital for alternative new industry • Long-term stakeholder involvement • Provide sustainable industry
Social services	• Stakeholder engagement • Support alternative options
Townsite infrastructure/buildings	• Stakeholder engagement to inform closure planning • Sale • Removal • Asset transfer.

Water storage dams

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Altered ecosystems • Catchment impact • Flora and fauna impact	• Fence • Breach wall • Rehabilitate • Restore natural drainage
Process water dams • Contaminated water/soil	• Remove water and dredge through plant (operational) • Rehabilitate
Siltation	• Draining system
Downstream shadow • Vegetation loss • Soil degradation	• Draining system
Long-term stability • Wall failure	• Geotechnical review and risk assessment
Water quality • Salinity • Nutrients	• Through-flow system • Catchment management
Safety • Injury or death	• Restrict access (fencing)
Post-mining land use	• Recreation • Pastoral • Water supply • Asset transfer • Other stakeholder-defined use.

Service infrastructure

ISSUES AND CONSEQUENCES	OPTIONS AND TECHNIQUES
Above-ground services (such as powerlines, roads, railways, airstrips, borefields, ports) • Soil contamination • Drainage obstruction • Vegetation loss	• Stakeholder engagement • Removal of infrastructure • Rehabilitate • Reinstate drainage • Asset transfer
Below-ground services (such as electrical cable, piping) • May be exposed during rehabilitation	• Remain buried depending on depth • Remove and salvage • Rehabilitate
Vent rises/escape ways and service tunnels • Injury or death	• Backfill and cap with engineered concrete structure • Waste disposal.

APPENDIX 3: TAILINGS DECOMMISSIONING PLAN

Before tailings deposition ceases, a leading practice activity is to proactively plan the decommissioning and rehabilitation of the facility, initiated by the operator and with the assistance of decommissioning specialists who coordinate the appropriate disciplines as required. As a minimum, engineering, geotechnical and environmental specialists will be needed; hydrologists (groundwater and surface water) and geochemists are usually needed to provide a complete and adequate conceptual decommissioning plan.

A decommissioning plan presents a detailed assessment of the current status of the facility and any further engineering works proposed as part of the final closure and rehabilitation of TSFs.

Information expected to be in a decommissioning plan or a TSF includes:

- a general description of the complete facility, deposition history, construction techniques used, and operational process
- a review of the general status of the structure and its contained tailings
- current landform and its relationship to final storage geometry and closure design
- a current survey plan of the facility (showing past and future staged earthworks)
- reconciliation of stored volume and calculated densities (and ongoing settlement), with expected values from the design report
- a review of the results of all various forms of monitoring and formal reviews
- an assessment of in-situ tailings properties, physical, geochemical and edaphic characterisation; stability; geotechnical, structural and durability and likely resistance to erosion
- contained materials, the likely closure implications, including toxicological and radiological characterisation, where needed
- the overall closure strategy for the TSF landform, addressing factors such as the retention or drainage of incident rainfall, cover types required and revegetation of covered or uncovered tailings
- long-term flood management strategies and a strategy for the containment or deposition of rainfall from a possible maximum precipitation event
- the sources and properties of materials to be used as part of the decommissioning, closure cover and rehabilitation process
- proposed surface drainage works
- civil engineering design, construction and, in consideration of risk, storm events and ongoing maintenance
- consideration and risk management of extreme events (such as drought, flood, fire, earthquake) after closure
- surface treatment to minimise erosion (via rock cover and/or vegetation) while sustaining vegetation and leading to proposed rehabilitation design and stabilisation works
- monitoring and audit requirements for the closure process and aftercare.

After TSF decommissioning, a competent person should assess the facility and prepare a report that:

- includes an as-built survey and comprehensive report
- notes deviations from the original decommissioning plan at were approved and implemented
- gives an outline of projected compliance through defined monitoring programs
- gives a projected timeline of monitoring and planned staged removal and gradual reduction of statutory liabilities.

GLOSSARY AND ACRONYMS

Abandoned mine or site
Mine where mining leases or titles no longer exist, and responsibility for rehabilitation cannot be allocated to any individual, company or organisation responsible for the original mining activities.

Acid and metalliferous drainage
Traditionally referred to as 'acid mine drainage' or 'acid rock drainage'; includes both acidic and near-neutral but metalliferous drainage.

Acid mine drainage (AMD)
Acidic drainage from mine wastes resulting from the oxidation of sulphides such as pyrite.

Acid-base accounting
An analytical technique that determines the maximum potential acidity that can be generated by oxidisation of sulphides compared with the neutralisation potential of rock or tailings. Also used to predict the potential of the material to be acid-producing, neutral or alkali-producing.

Adaptive management
A systemic process for continually improving management policies and practices by learning from the outcomes of operational programs. The ICMM's *Good practice guidance on mining and biodiversity* refers to adaptive management as 'do–monitor–evaluate–revise'.

Analogue
Unmined feature against which a mined feature may be compared.

Angle of repose
The maximum angle from horizontal at which a given material will rest on a given surface without sliding or rolling.

Backfilling
Refilling of an excavation or void.

Baseline data
Studies undertaken to describe the conditions that exist before an action is taken.

Batter slope
Recessing or sloping a wall back in successive courses.

Berm
A horizontal shelf or ledge built into an embankment or sloping wall to break the continuity of an otherwise long slope to strengthen and increase the stability of the slope, to catch or arrest slope slough material, or to control the flow of run-off water and erosion.

Biodiversity
The variety of life on our planet, measurable as the variety within and between species and the variety of ecosystems.

Block model
A three-dimensional model of the distribution of ore and waste materials with different geochemical properties (metalliferous mines).

Bund
An earthen retaining wall. A low embankment often constructed around potential spillage areas to reduce the risk of environmental contamination by retaining the volume of any potential spillage.

Capillary break
A layer of coarse material placed with a limited capillary rise between finer-textured materials to prevent the vertical movement of water (and associated salts) by surface tension from the lower, finer-textured material into the upper finer-textured material.

Care and maintenance
Phase following a temporary cessation of operations, when infrastructure, plant and equipment remain intact and are maintained in anticipation of production recommencing. May also be referred to as 'temporary closure'; such a site may be referred to as 'inactive'.

Closure planning
A process that extends over the mine life cycle and that typically culminates in tenement relinquishment. Includes decommissioning and rehabilitation. The term 'closure' alone is sometimes used to indicate the point at which operations cease, infrastructure is removed and management of the site is largely limited to monitoring (ICMM).

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

Community
In mining industry terms, the inhabitants of immediate and surrounding areas who are affected by a mining operation's activities. 'Local community' usually indicates the community in which operations are located and may include Indigenous and non-Indigenous people.

Community engagement
Deliberate and strategic liaison with communities and individuals who live in close proximity to, and are potentially affected by, mining activity. Effective engagement typically involves identifying and prioritising stakeholders, conducting dialogue to understand their interest in an issue and any concerns they may have, exploring with them ways to address these issues, and providing feedback on actions taken.

Community impact
Detrimental harm to the neighbouring community.

Completion criteria
Agreed standards or levels of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area ceases.

Consultation
Providing information about, advising on and seeking responses to an actual or proposed event, activity or process.

Contaminated site
A site at which hazardous substances occur at concentrations above background levels and where assessment shows that it poses, or is likely to pose, an immediate or long-term hazard to human health or the environment (National Environment Protection (Assessment of Site Contamination) Measure 1999).

Decommissioning
Begins with the cessation of production, when infrastructure, plant and equipment are isolated from services such as power and water. Commonly includes the removal (deconstruction or demolition) of unwanted plant and equipment. Individual facilities may be decommissioned and removed if no longer required, while mining and processing operations continue.

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 (for example, minimum, maximum, best).

Desiccation
Drying, shrinkage and cracking of the tailings surface by solar evaporation.

Dewatering
Removal of water from a slurry by thickening, filtration or centrifuging.

Dispersive soil
Soil that is structurally unstable and disperses in water into basic particles (such as sand, silt and clay). Dispersive soils tend to be highly erodible and present problems for successfully managing earthworks.

Downstream or outer face
The external perimeter of a TSF exposed to the environment.

Ecosystem
A system in which the members benefit from each other's participation via symbiotic relationships (positive sum relations). It is a term that originated from biology and refers to self-sustaining systems.

Ecosystem function analysis
A procedure used by some mines to assess ecosystem function and recovery following disturbance. The three components of ecosystem function analysis are landscape function analysis, vegetation dynamics and habitat complexity

Embankment
A tailings or water containment wall.

Encapsulation
Surrounding a reactive waste with benign materials that isolate the reactive waste material from oxygen and/or water flow.

Endemic species
Native plants or animals restricted to a specific locality or geographical region.

Enduring Value
The Australian Minerals Industry Framework for Sustainable Development. Established by the Minerals Council of Australia, it aligns with global industry initiatives and, in particular, provides critical guidance on the ICMM Sustainable Development Framework Principles and their application at the operational level. For further information, refer to MCA (2004).

Engagement
At its simplest, communicating effectively with the people who affect and are affected by a company's activities (its stakeholders). A good engagement process typically involves identifying and prioritising stakeholders, conducting a dialogue with them to understand their interest in an issue and any concerns they may have, exploring with them ways to address the issues, and providing feedback to them on actions taken. At a more complex level, engagement is a means of negotiating agreed outcomes over issues of concern or mutual interest.

Environmental impact
Detrimental harm to the environment.

Environmental indicator
A parameter (or a value derived from a parameter) that provides information about an environmental phenomenon.

Environmental management system
A tool for managing an organisation's impact on the environment. It provides a structured approach to planning and implementing environmental protection measures.

Evaporation
The process by which water is converted from liquid to vapour and is lost to the atmosphere.

Exploration
The search for mineral deposits. Includes the delineation of the deposit by means of drilling and sampling.

Functional ecosystem
An ecosystem that is stable (not subject to high rates of erosion), is effective in retaining water and nutrients and is self-sustaining.

Geomembrane
A manufactured low-permeability sheet, such as high-density polyethylene.

Geotechnical
The engineering of the ground and or earthen structures.

Groundwater
Water beneath the earth's surface that fills pores between porous media—such as soil, rock, coal and sand—usually forming aquifers. In some jurisdictions the depth below the soil surface is also used to define groundwater (although different states use different depths).

Hazard
A source of potential harm.

Heap leach
Using chemicals to dissolve minerals or metals out of an ore heap. During heap leaching of gold, a cyanide solution percolates through crushed ore heaped on an impervious pad or base pads.

Hydraulic conductivity
A measure of the ability of a porous material to pass water. Otherwise known as (water) permeability.

International Financial Reporting Standards (IFRS) estimate
Includes only the liability that exists at the balance sheet reporting date (31 December or 30 June).

Lag time
Time delay between the disturbance or exposure of acid-generating materials and the onset of acidic drainage.

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

Leading practice
Best available current practice promoting sustainable development.

Licence to operate
The permission that government gives to the mining industry through formal legislative and legal agreements to mine and produce minerals from specific operations.

Life cycle
All the steps in the production of a product or the development of a mine. A company needs to examine each step in the life cycle of a product, including those that are easily overlooked, such as the fate of the product after its useful life. The steps typically include the extracting and processing of materials; manufacturing, transportation and distribution; use, reuse and maintenance; recycling and final disposal.

Liner
A low-permeability base comprising compacted clay and/or a geomembrane or geosynthetic (clay in a geotextile 'sandwich').

Local provenance
Plants the native area of which is close to the area where they are going to be planted (for example, in the same local area).

Low-grade ore stockpile
Material that has been mined and stockpiled, with sufficient value to warrant processing, either when blended with higher grade rock or after higher grade ore is exhausted, but often left as 'waste'.

Mining activity
The extraction, concentration and/or smelting of economic minerals from a mineral deposit. Includes exploration, the development of mineral deposits, the construction of the mine, mining (extracting and processing the ore) and closure.

Natural analogue
An unmined landform to which a mined landform can be compared to develop sustainable post-mining landforms.

Net present value (NPV)
A measurement used to decide whether to proceed with an investment. It is calculated by adding together all the expected benefits and subtracting all the expected costs of the investment, now and in the future. If the NVP is negative, then the investment cannot be justified by the expected returns. If the NVP is positive, then it can be justified financially.

Non-government organisation (NGO)
A non-profit group or association organised outside institutionalised political structures to realise particular social objectives (such as environmental protection) or serve particular constituencies (such as Indigenous peoples). NGO activities range from research, information distribution, training, local organisation, and community service to legal advocacy, lobbying for legislative change, and civil disobedience. NGOs range in size from small groups within a particular community to huge membership groups with a national or international scope.

Operational risks
Risks that are focused on aspects of an operation that may be more systemic to the mining process and the day-to-day operation of a mine.

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

Overtopping
Water or tailings slurry breaching the top of the containment structure.

Pioneer species
The first species to recolonise an area of disturbance.

Post-mining land use
A land use that occurs after the cessation of mining operations.

Reactive waste
Waste that reacts on exposure to oxygen.

Recalcitrant species
Species that are difficult to re-establish.

Reclamation
Treatment of previously degraded and often contaminated land to achieve a useful purpose. Often used outside Australia instead of 'rehabilitation'.

Rehabilitation
Rendering a TSF safe, stable and non-polluting in the long term, 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
Cleaning up or mitigating contaminated soil or water.

Remnant vegetation
Native vegetation remaining after widespread clearing has taken place.

Resource stewardship
A program of actions to ensure that resource inputs to a process, including minerals, water, chemicals and energy, are being used in the most efficient and appropriate way.

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

Riparian
Pertaining to, or situated on, the bank of a body of water, especially a watercourse such as a river.

Risk
The chance of something happening that will have an impact on objectives. It is often specified in terms of an event or circumstance and the consequences that may flow from it.

Risk analysis
The systematic process used to understand the nature of risk and to reduce it. It provides the basis for risk evaluation and decisions about risk treatment.

Risk control
An existing process, policy, device, practice or other action that acts to minimise negative risk or enhance positive opportunities.

Risk criteria
The terms of reference by which the significance of a risk is assessed.

Risk evaluation
The process of comparing the level of risk against risk criteria.

Risk management
The process and structures that are directed towards realising potential opportunities while managing adverse effects.

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

Sedimentation
The separation of solids from an aqueous slurry.

Seepage control system
May include a compacted foundation or liner (compacted clay or geomembrane) and an under-drainage collection system.

Slurry
A finely divided solid that has settled out from thickeners.

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

Soil cover
One or more layers of soil-like materials intended to limit the percolation of rainfall or the ingress of oxygen, or both, into AMD-generating materials.

Stakeholders
The people and organisations who may affect, be affected by or perceive themselves to be affected by a decision, activity or risk.

Stewardship
An integrated program of actions aimed at ensuring that all materials, processes, goods and/or services that are produced, consumed and disposed of along the value chain are handled in a socially and environmentally responsible manner. Encompasses product, process and resource stewardship. Also known as materials stewardship.

Strategic risks
Risks that relate to the interdependencies between an operation's activities and the broader business environment.

Succession
The natural process of community change that culminates in the development of the climax community of an area.

Supernatant water
The water ponded on a tailings surface following the sedimentation of the deposited tailings slurry.

Surface water
All water naturally open to the atmosphere, except oceans and estuaries.

Sustainable development
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Tailings
A combination of the fine-grained solid material remaining after the recoverable metals and minerals have been extracted from crushed and ground mined ore, and any process water remaining.

Tailings management
Managing tailings over their life cycle, including their production, transport, placement and storage, and the closure and rehabilitation of the TSF.

Tailings slurry
Tailings solids embedded in process water that are produced in the processing plant at a low density, which beach at a flat slope, segregate down the beach, and produce considerable supernatant water.

Tailings storage facility (TSF)
An area used to contain tailings; its prime function is to achieve solids sedimentation, consolidation and desiccation, and to facilitate water recovery or removal without affecting the environment. Refers to the overall facility and may include one or more tailings storages.

Tenement
A legal instrument providing access to land for the purposes of mining.

Thickened tailings
Tailings thickened to a high density, which beach at a steeper slope and segregate less than tailings slurry, producing far less supernatant water.

Under-drainage
The provision of drains beneath a tailings deposit to facilitate their drain-down.

Upstream method, construction or raising
The construction of tailings containment walls in an upstream direction on top of consolidated and desiccated tailings, using waste rock or tailings.

Waste rock
Uneconomic rock extracted from the ground during a mining operation to gain access to the ore.

Water cover
The layer of surface water (for example, in a TSF or pit) or groundwater (for example, in a backfilled pit) intended to limit the ingress of oxygen into AMD-generating materials.

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