

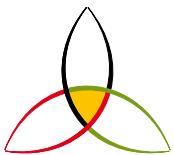


Australian Government

Department of Industry
Tourism and Resources

BIODIVERSITY MANAGEMENT

LEADING PRACTICE SUSTAINABLE
DEVELOPMENT PROGRAM FOR
THE MINING INDUSTRY



SOCIAL
ECONOMIC
ENVIRONMENTAL

BIODIVERSITY MANAGEMENT

LEADING PRACTICE SUSTAINABLE
DEVELOPMENT PROGRAM FOR
THE MINING INDUSTRY



FEBRUARY 2007

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Leading Practice Sustainable Development Program for the Mining Industry

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CONTENTS

ACKNOWLEDGEMENTS	vi
FOREWORD	ix
1.0 INTRODUCTION	1
2.0 THE IMPORTANCE OF BIODIVERSITY	3
2.1 What is biodiversity?	4
2.2 Biodiversity, society and mining	4
2.3 Social licence to operate	5
CASE STUDY: Community partnerships at Tiwest Cooljaroo	6
2.4 Business case for biodiversity management	8
2.5 Key biodiversity threats and opportunities	9
3.0 ASSESSMENT AND PLANNING	11
3.1 General overview of baseline monitoring	11
3.2 Biodiversity, protected areas and no-go zones	12
CASE STUDY: Shelburne Bay – government and community action	13
3.3 Landscape/catchment level planning	15
CASE STUDY: Junction Reefs – regional biodiversity enhancement	17
3.4 Risk assessment–identification of critical risks early, direct v indirect, precautionary principal	18
3.5 Assessing impacts to enable minimisation, mitigation and rehabilitation	20
CASE STUDY: Community engagement to help conserve a significant species – the Glossy Black Cockatoo	21
3.6 Setting biodiversity objectives	22
3.7 Planning for closure	23
CASE STUDY: Taking biodiversity into account in mine closure – Timbarra Gold Mine	24
4.0 INTEGRATED BIODIVERSITY MANAGEMENT	26
4.1 Holistic land management	28
4.2 Maintaining ecological services	28
4.3 Biodiversity offsets	29
4.4 Building community partnerships	31
CASE STUDY: Effective partnerships promote threatened fauna recovery – Arid Recovery	32
4.5 Managing impacts	33
CASE STUDY: Rehabilitation of dieback affected areas in jarrah forest	36
CASE STUDY: Significant species management as a surrogate for ecosystem protection–pygmy perch	39
4.6 Introduced organisms and species	42
4.7 Rehabilitation	44
CASE STUDY: Estimating genetic provenance for spinifex (Triodia species)	45

CASE STUDY: Using the smoke techniques for rehabilitation of native Australian species	46
4.8 Research for improvement	51
5.0 MONITORING PERFORMANCE	52
5.1 Why monitor?	53
5.2 Who to involve?	54
5.3 What to monitor?	55
CASE STUDY: The use of invertebrates as indicators to monitor development of mine rehabilitation	60
5.4 Key performance indicators and completion criteria	65
5.5 Reporting	66
6.0 CONCLUSIONS	68
REFERENCES	70
FURTHER READING AND WEBSITES	74
GLOSSARY	76

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Mr John Allan

Chair - Biodiversity Management Working Group
Group Manager Environment
Newcrest Mining Limited

www.newcrest.com.au

Dr Owen Nichols

Principal Author - Biodiversity Management Working Group
Principal
Environmental Management and Research Consultants



Ms Kirrily Noonan

Secretariat - Working Group
Sustainable Mining Section
Department of Industry, Tourism and Resources

www.industry.gov.au



Ms Techa Beaumont

Mineral Policy Institute

www.mpi.org.au



Dr Kingsley Dixon

Director, Science
Kings Park and Botanic Garden

www.bgpa.wa.gov.au



Mr Cormac Farrell

Policy Officer - Environment
Minerals Council of Australia

www.minerals.org.au



Mr John Gardner

Environmental Manager - Mining
Alcoa World Alumina Australia

www.alcoa.com.au



Prof Jonathan Majer

Head, Department of Environmental Biology
Curtin University of Technology

www.envbio.curtin.edu.au



Dr Libby Mattiske

Managing Director
Mattiske Consulting Pty Ltd

www.mattiske.com.au



Mr Dan McLaughlin

Manager Environment
BHP Billiton Limited

www.bhpbilliton.com



Mr Mark Nolan

Senior Environmental Officer
NSW Department of Primary Industries

www.dpi.nsw.gov.au



Mr Paul Smith

Manager - Environment and Community Relations
Consolidated Rutile Limited

www.consrutile.com.au



Dr Ross Smith

Director
Hydrobiology Pty Ltd

www.hydrobiology.biz

The Biodiversity Management Working Group would also like to acknowledge that this handbook has drawn significantly on the *ICMM Good Practice Guidance for Mining and Biodiversity* (ICMM 2006). Readers should also consult this valuable resource for more detailed coverage of various areas and the presentation of an international perspective.



FOREWORD

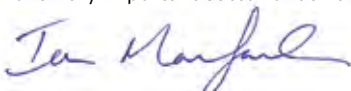
The Australian mining industry is well aligned to the global pursuit of sustainable development. A commitment to leading practice sustainable development is critical for a mining company to gain and maintain its 'social licence to operate' in the community.

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

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

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

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



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



1.0 INTRODUCTION

This handbook addresses the theme of biodiversity management, which is one theme in the Leading Practice Sustainable Development Program. The aims of the Program are to identify the key issues affecting sustainable development in the mining industry and provide information and case studies that illustrate a more sustainable basis for the mining industry.

The leading practice handbooks are relevant to all stages of a mine's life—exploration, feasibility, design, construction, operation and closure – and to all facets of an operation, this is particularly true for this handbook. Leading practice biodiversity management starts at the very beginning of a mining project, and continues after mine closure and lease relinquishment. It is not limited to the immediate area affected by operations, but must take account of all relevant site, local, regional, national and even international aspects.

The primary audience for this handbook is management at the operational level—those who are responsible for implementing leading practice at mining operations. It is also relevant to people with an interest in leading practice biodiversity management in the mining industry, including environmental officers; mining consultants; governments and regulators; non-government organisations; neighbouring and mine communities; and students. All users are encouraged to work together in partnership, taking up the challenge to continually improve the mining industry's standards of biodiversity management, as part of its sustainable development performance. Improved performance can be achieved through applying the principles outlined in these handbooks.

This handbook outlines the key principles and procedures now recognised as leading practice for assessing biodiversity values, namely:

- identifying any primary, secondary or cumulative impacts on biodiversity values
- minimising and managing these impacts
- restoring conservation values
- managing conservation values on a sustainable basis.

Leading practice biodiversity management requires that relevant issues are addressed on a whole-of-lease basis, always in consultation with government and other key stakeholders, and increasingly in partnership with non-government organisations.

Research and monitoring are essential components of leading practice for the management of impacts on biodiversity, and their rehabilitation following disturbance. Companies that achieve the highest biodiversity management standards inevitably use findings of research and monitoring programs for continuous improvement, a key element of their environmental management system (EMS).

This handbook describes why biodiversity is important, the business case for biodiversity management, and the leading practice approaches to biodiversity conservation and rehabilitation. A number of case studies illustrate various aspects of biodiversity management that reinforce the approaches outlined.

This leading practice handbook complements other publications, in addition to providing information specific to biodiversity management in the Australian context. In particular, this handbook complements the International Council on Mining and Metals (ICMM) *Good Practice Guidance for Mining and Biodiversity* (ICMM 2006), which was developed following extensive discussions with the World Conservation Union (IUCN).



2.0 THE IMPORTANCE OF BIODIVERSITY

In 1992, Australia was one of 188 countries that ratified the Convention on Biological Diversity at the Rio Earth Summit. Through this, the global community acknowledged that biodiversity is 'a common concern of humankind, and an integral part of the development process'. It recognised that while biodiversity conservation can require substantial investments, it brings significant environmental, economic and social benefits in return. The convention recognises that ecosystems, species and genes are used for the benefit of humans. However, this should be done in a way and at a rate that does not lead to the long-term decline of biological diversity. The principles contained within the Convention on Biological Diversity and other international conventions on sustainable development have increasingly become an integral part of the way leading practice Australian mining companies do business.

Unlike much of the world, a large range of endemic species and ecosystems are supported in many parts of the Australian continent. Australia is more biodiverse than 98 percent of other countries, and is one of the 19 mega-biodiverse countries on earth. Through 65 million years of evolutionary isolation as an island continent, Australia has developed species and ecosystems that are world class and unique—80 percent of species are found only in Australia. As a result of these long periods of genetic isolation Australia's biodiversity has adapted in remarkable ways to some of the world's poorest soils and most hostile environments.

Understanding how Australian species operate ecologically and physiologically presents challenges particularly for managers of biodiversity. Equally there is now an intersection between geological anomalies (often associated with mineralisation) that have acted as foci for evolution of species of high conservation value and the mineral value of these anomalies. Resolving effective means for developing the knowledge base to protect, manage and rehabilitate Australia's unique species and ecosystems represents a significant challenge for industry and scientists.

The significance of some regions has been highlighted nationally and internationally through programs such as Biodiversity Hotspots www.biodiversityhotspots.org. On the other hand, many parts of Australia have been subjected to a range of degradation processes such as clearing for agriculture, land salinisation, grazing, drought, logging, the introduction of problem plant and animal species, construction of water impoundments and urbanisation.

The purpose of this leading practice handbook is to provide the mining industry and its key stakeholders with the information they need to understand and manage biodiversity.

2.1 What is biodiversity?

As an overriding principle, it is important that all involved in the mining industry recognise that biodiversity has important environmental, social and cultural values. Biodiversity can mean different things to different stakeholders. The definition below reflects the intrinsic value of biodiversity. However, for many people, biodiversity also has significant social, cultural and spiritual values. This is especially true for indigenous peoples in Australia and other countries where the protection and management of biodiversity has important livelihood and cultural implications.

Natural or biological diversity, or biodiversity, is all life on earth—plants, animals, fungi and microorganisms—as well as the variety of genetic material they contain and the diversity of ecological systems in which they occur. It includes the relative abundance and genetic diversity of organisms from all habitats including terrestrial, marine and other aquatic systems.

Biodiversity is thus usually considered at three different levels: genetic diversity, species diversity and ecosystem diversity.

- Genetic diversity refers to the variety of genetic information contained in all living things. Genetic diversity occurs within and between populations of species as well as between species.
- Species diversity refers to the variety of living species.
- Ecosystem diversity relates to the variety of habitats, biotic communities, and ecological processes, as well as the diversity present within ecosystems in terms of habitat differences and the variety of ecological processes.

Evolutionary change results in an ongoing process of diversification within living things. Biodiversity increases when new genetic variation is produced, a new species evolves or a novel ecosystem forms; it decreases when the genetic variation within a species decreases, a species becomes extinct or an ecosystem is lost or degraded. This concept emphasises the interrelated nature of the living world and its processes.

Based on *Southwest Australia Ecoregion Initiative (2006)*

2.2 Biodiversity, society and mining

Humanity is dependent on biological systems and processes for its sustenance, health, well-being and enjoyment of life. Biodiversity is the basis of numerous ecosystem services that keep the natural environment alive, ranging from maintaining watersheds that provide fresh water, to pollination and nutrient cycles, and the maintenance of clean air and atmospheric gases. We derive all of our food and many medicines and other products from wild and domesticated components of biodiversity. Biodiversity is also of value for aesthetic, spiritual, cultural, recreational and scientific purposes.

The interdependence between humanity and biodiversity is critical for all peoples, because all communities ultimately depend on biodiversity services and resources. Some people lead lifestyles that are more directly dependent on biodiversity than others, their culture, history and identity being intimately associated with the natural environment and its systems. Different cultures and peoples perceive and value biodiversity in different ways as a consequence of their distinct heritages and experiences. But even though many people's dependence on biodiversity has become less tangible and apparent, it remains critically important for all communities.

While the known benefits of resources and services provided by biodiversity are considerable, there remain significant gaps in our knowledge that limit our ability to assess the true value of its various elements. Our global understanding of inter-ecosystem interactions and dependencies is still evolving. The enormous diversity of life is of crucial intrinsic value as it gives greater resilience to ecosystems and organisms. It empowers a natural system to absorb and recover from detrimental human impacts, and enhances sustainability.

Our appreciation of significant threats to biodiversity, and the importance of preventing/avoiding, halting and reversing processes of degradation continues to improve. In recent decades ecosystems have degraded more rapidly and extensively, due to human pressures, than at any time in history. This has placed serious threats on basic ecosystem services we all depend upon.

Through land disturbance, mining can have significant local and direct impacts on biodiversity. Broadscale and indirect impacts can also result from associated land use changes.

At the same time, the mining industry has contributed considerable knowledge and expertise to the understanding of biodiversity management and rehabilitation. It is important that the industry recognises that it not only has a responsibility to manage its impacts on biodiversity, but also has the opportunity to make a significant contribution to biodiversity conservation through the generation of knowledge, and the implementation of initiatives in partnership with others.

2.3 Social licence to operate

Mining activities often occur in remote environments where local communities engage in subsistence agricultural practices or sustainable livelihoods based on surrounding natural resources. In these circumstances, the human (social and economic) dimensions of biodiversity take on critical importance. This is particularly true in the rural areas of developing countries, where entire communities are directly dependent on biodiversity and ecosystem services and therefore more vulnerable to their degradation.

Public concern over biodiversity loss and ecosystem damage is reflected in a growing number of initiatives. These range from civil society and local community action to international, national and local laws, policies and regulations aimed at protecting, conserving or restoring ecosystems. To maintain their social licence to operate, mining companies are responding to expectations and pressures for stricter measures to conserve and manage remaining biodiversity. They are increasingly being called upon to:

- make 'no go' decisions on the basis of biodiversity values, which may include pristine, sensitive or scientifically important areas, the presence of rare or threatened species, or where activities pose unacceptable risks to ecological services relied upon by surrounding populations
- alter the project development cycle where there is insufficient baseline information or where scientific uncertainty mandates a precautionary approach in relation to mitigating or avoiding impacts on biodiversity; and, where practicable, mitigate impacts and positively enhance biodiversity outcomes in areas where they currently operate.

Responsible management of biodiversity, in conjunction with key stakeholder groups such as regulators and indigenous peoples, is a key element of leading practice sustainable development in the mining industry. Engagement with these groups is discussed further in the Leading Practice Handbooks on *Community Engagement and Development* and *Working with Indigenous Communities*.

CASE STUDY: Community partnerships at Tiwest Cooljaroo

Tiwest's Cooljarloo site is 170 kilometres north of Perth, and produces heavy mineral concentrates from dredging and dry mining operations.

Through the site building strong partnerships with government and local communities, and for its commitment to sustainable development principles, the operation won the minerals category in the 2006 Banksia Awards. For those at Tiwest Cooljaroo, the outcome of implementing leading practice approaches is the overwhelming support from local communities, which in turn, is delivering greater security for the company's 'social license to operate'.

Tiwest's philosophy of adding value in partnership is apparent in biodiversity partnerships with the Perth Zoo, Department of Environment and Conservation and local schools. Joint work with the Department of Conservation and Land Management's (CALM) Western Shield program has seen regional fox numbers reduced to the point where there have been



successful releases of woylies, Tammar Wallabies and Quenda into nearby Nambung National Park.

Left: Environment Minister Mark McGowan, Cathy Henbeck (DEC) and David Charles (Tiwest) with Quenda at Nambung National Park

The Nightstalk Marsupial spotlighting program in partnership with the Perth Zoo has directly engaged the local community and workforce in fauna conservation. Partnerships with local schools provided environmental education to children and assisted them to eliminate legacies such as an un-rehabilitated borrow pits.

The Cooljarloo operation is based on an approach to sustainable development that incorporates a broad range of leading practice approaches, including:

- the collection of seed from mature plants before disturbance
- materials segregation (topsoil, clay overburden, processed material) that contributes to the rehabilitation and the establishment of landforms, particularly the management of fine clay slurries or 'slimes'
- supporting the recolonisation of locally extinct faunal species within nearby national parks
- partnerships with local indigenous business enterprises for seed collection and other services. For example, Tiwest's partnership with Billinue Aboriginal Community is now in its 12th year with over a million dollars worth of local provenance seed collected and 700 ha of disturbed land revegetated
- ongoing partnerships with a wide cross-section of the local community covering



educational projects, environmental management and support for community organisations.

Further information on the environmental and community development initiatives being undertaken at Tiwest's Cooljarloo operation can be obtained by visiting www.tiwest.com.au.

Left: Kade Hornell, Mal Ryder and Ken Capeswell of Billinue

A range of sustainable development policy frameworks have been developed by industry and other organisations that are now acting as drivers for improved practice. One such approach is that by the International Council on Mining and Metals (ICMM) which adopted a set of 10 Sustainable Development Principles in 2003 to harness the industry's commitment to sustainable development within a strategic framework (ICMM, 2003). ICMM's Sustainable Development Framework states that member companies are required to 'contribute to conservation of biodiversity and integrated approaches to land use planning'.

To give practical and operational effect to the ICMM commitments in the Australian context, the Minerals Council of Australia (MCA) developed *Enduring Value - the Australian Minerals Industry Framework for Sustainable Development* (MCA 2004). Commitment to *Enduring Value* is a condition of membership of the MCA, however non-MCA companies are also eligible to become signatories to this framework. The development of *Enduring Value* provides the industry with a framework for implementing sustainable development, including the management of biodiversity, through all aspects of operations, with a strong emphasis on supporting continual improvement.

2.4 Business case for biodiversity management

Not only is sound biodiversity management an ethical and moral imperative, it also makes good business sense. The mining industry is reliant on biodiversity and associated values. Healthy ecosystem services, for example, supply key raw materials such as water for processing. Stable climatic conditions and landforms allow operations to treat and manage waste.

Conversely, the failure to adequately avoid or minimise the impacts of operations on biodiversity poses growing threats and risks that can materially affect business's operations. Historically, the social and economic costs of changes in biodiversity have been poorly addressed in impact assessments. Resultant poor decision making has impacted on the reputation of the mining industry. A proactive and forward looking approach to the management of biodiversity and responding to society's priorities for biodiversity conservation are now essential for leading practice sustainable development in the mining industry.

The risks and impacts to business of the failure to adequately manage biodiversity issues can include:

- increased regulation and liability to prosecution
- increased rehabilitation, remediation and closure costs
- social risks and pressure from surrounding communities, civil society and shareholders
- restricted access to raw materials (including access to land, both at the initial stages of project development and for ongoing exploration to extend the lifetime of existing projects)
- restricted access to finance and insurance.

In some instances the sensitivity of the environmental and cultural values associated with particular elements of biodiversity may result in the exclusion of exploration and mining activities.

In recent years, some projects have undertaken an initial desktop review and reconnaissance of potential biodiversity issues in exploration and mining lease areas. This information can be used for defining the risk of investment and the potential for a 'fatal flaw' in the environmental impact processes, thereby reducing the social, economic and environmental risks. This also enables informed decisions to be made on the likelihood of a project progressing beyond the pre-feasibility stage, with a consequent saving on time and resources where progress is unlikely.

Conversely, positive and proactive biodiversity management can offer opportunities and benefits including:

- shorter and less contentious permitting cycles, as a result of better relationships with regulatory agencies
- reduced risks and liabilities
- improved community and NGO relations and partnerships
- improved employee loyalty and motivation.

For these reasons, the minerals industry is increasingly adopting measures to conserve and sustainably manage natural resources. Gaining the support of international institutions such as the International Finance Corporation, World Bank and private financial organisations is now conditional on complying with internationally-recognised biodiversity principles and

standards such as the Equator Principles voluntary social and environmental standards. Leading financial lenders and export credit agencies are increasingly integrating assessments of biodiversity impacts into their mainstream financial decisions. These financial institutions see environmental assessment as a key element of the overall risk management process.

Increasingly, a mining company's ability to achieve high standards of biodiversity management is recognised as a competitive advantage. As a result companies that develop sophisticated policies and practices for managing biodiversity enjoy greater opportunity, particularly with respect to land access.

2.5 Key biodiversity threats and opportunities

Australia possesses native biodiversity that is world class. There are more unique mammal, invertebrate and flowering plant species than 98 percent of other countries. Discoveries such as the living fossil, the Wollemi Pine near Sydney highlight the botanical richness of the continent.

Such richness also brings challenges. A key impediment for managing this biodiversity is the limited taxonomic coverage to date, with estimates that only one in four species in Australia is known (PMSEIC 2005). For the minerals industry this represents significant uncertainty in pre-mining biodiversity assessment particularly in biodiverse regions.

There is a growing recognition of the critical role that business can play (in partnership with governments, the community and researchers) to change the threats to biodiversity into opportunities. Through these strategic partnerships impacts that have taken place over the last 200 years due to increasing land clearing, unsustainable land management practices, introduced species and fragmentation of the landscape can be understood, minimised and, where possible, reversed. As one of the major business groups in Australia, the mining industry has taken the opportunity to play a leading role in biodiversity conservation.

As defined in State of the Environment reporting (2006), key threats to biodiversity in Australia include:

- our lack of understanding of biodiversity values (particularly the role of many species and ecosystems) and their role in ecosystem functioning
- the undervaluing of the contribution made by species and ecosystems to the well-being of the Australian community
- the rate of continuing loss at the genetic, species, ecosystem and landscape levels due to broadscale clearing (although this is reducing), fragmentation, changed fire regimes, total grazing pressure, landform and soil degradation, the range of threatening processes and associated cumulative impacts
- the influence of introduced plants, animals and pathogens, particularly invasive plant species, weeds, feral predators, and plant and animal diseases

- the recent shifts in climatic trends, with many sectors of Australia facing decreasing rainfall and associated hydrological shifts
- fragmentation and degradation processes influencing the ability of systems and their associated ecosystem services to be maintained.

Extinction is also of particular significance, since the loss of any species diminishes biodiversity. In pure economic terms, extinction equates to lost opportunity (for example, new medical or other products), and diminishes the collective well-being of society. Extinctions can also have a very significant impact within communities, particularly where there is a strong spiritual and/or emotional significance attached to the species.

In recent decades, despite increasing community interest in biodiversity, there is often a lack of long-term commitment of resources required for effective biodiversity research and management in Australia. The mining industry is taking up this opportunity to significantly assist biodiversity conservation and recovery through the following mechanisms:

- support of researchers, industry groups and consultants undertaking biodiversity studies (for example, on values, impact assessment and management of threats, and maximising return of values on disturbed areas)
- developing human resources, skills and knowledge in areas that could assist in these complex matters
- developing partnerships with communities, conservation groups and other organisations to address this issue
- encouraging young graduates in biodiversity investigation and research through traineeships, graduate studies and partnerships
- developing, maintaining and sharing databases with government and researchers for biodiversity data (for example, Western Australia's Alcoa Frogwatch program, and the sharing of data that took place as part of the Western Australia Regional Forest Agreement process)
- sharing through publishing key research findings, for example the jointly Government and mining industry funded Pilbara Bibliographic Database
- maintaining the balance between field biologists/scientists and those responsible for management of land, water and biodiversity values
- leading through the development of best practice research and processes.

Mitigation and offsets are being increasingly considered by some states, including Western Australia, New South Wales, Victoria and Queensland (see Section 4.3). Mitigation generally refers to actions taken to avoid, reduce or compensate for the effects of (direct or indirect) environmental damage. Offsets refer to actions aimed at compensating for unavoidable damage. When applied, these concepts can effectively balance access to mineral resources with 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.



3.0 ASSESSMENT AND PLANNING

KEY MESSAGES

- Prior to undertaking any operations, mining companies need to identify the biodiversity values present in a particular area, determine key risks to biodiversity, and enable the design of management programs, rehabilitation and closure objectives.
 - Mining may be excluded from areas deemed to have significant biodiversity values through either regulation or the voluntary adoption of guidelines.
 - Landscape/catchment level planning enables mining companies to address both the direct and indirect impacts of their activities.
 - Consideration should be given to cumulative impacts during planning.
 - To optimise biodiversity management, risk assessment procedures need to be closely linked to the assessment of impacts, to ensure that all relevant information is obtained and used in the decision-making process.
 - Biodiversity objectives should be developed in consultation with all stakeholders, and linked to specific, measurable targets as part of the completion criteria developed for the mine closure plan.
 - Conservation and sustainable management of biodiversity values during mine closure planning is an ongoing process. Leading practice requires that it start from the earliest moments of project planning and development, and continue throughout the life of an operation.
-

3.1 General overview of baseline monitoring

Prior to undertaking any operations, mining companies need to delineate the biodiversity values in a particular area. This is influenced by a range of social and economic factors, and the resulting information is essential for the identification of key risks to biodiversity, and the effective design of management programs, rehabilitation and closure objectives.

Baseline monitoring involves studying some element of biodiversity, that is not expected to change without being disturbed. In determining what baseline monitoring is required, it is critical to understand the range of influential factors within a specific environment. 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 initial phases of baseline monitoring involve reviewing background information available on biodiversity values within the local, regional, national and international context. Some state government agencies have published a series of guidance statements for baseline biodiversity studies in different bioregions (for example, the Environmental Protection Agency 2004a,b). This helps ensure minimum standards of assessment, and promotes the integration of localised baseline surveys into a broader regional context. Further discussion of landscape level planning is at Section 3.3.

The mining industry has often funded biodiversity surveys and research within areas subject to exploration and mining operations. Despite the challenges of comparing different regional datasets, more stakeholders are looking to co-operate and avoid isolated 'data silos'.

At the national scale there has been a shift towards developing consistency in standards (e.g. the National Vegetation Information System (NVIS), BIOCLIM, mapping standards, nomenclature consistency for species). This shift towards consistency has facilitated regional predictions on the threats that introduced plants, diseases and animals may have on the environment.

Cooperative research by government researchers, consulting scientists and a range of mining companies has resulted in increased understanding of the relationships between underlying geology, landforms, soils, climate and resulting ecosystems. This major advancement illustrates that significant synergy can develop from the joint research efforts of botanists, ecologists, foresters, hydrologists, geologists, geomorphologists and soil scientists.

3.2 Biodiversity, protected areas and no-go zones

The practice of establishing protected areas or those set aside for special or restricted use is used throughout the world to ensure long-term conservation of biodiversity values. Current legislation excludes mining from areas that possess particularly high conservation and biodiversity values. In such cases, mining and certain other land and water uses are deemed incompatible with the environment's long-term sustainability.

Industry, governmental and non-governmental organisations have sought to create guidelines on no-go zones for mining both nationally within countries, and globally through international conventions and agreements. International mining companies who are members of the ICMM, and Australian members of MCA, have agreed not to mine in existing World Heritage Areas. Dialogue continues to further the consensus on measures necessary to maintain the values of other protected areas.

The IUCN World Commission on Protected Areas, the peak global conservation network on protected areas, designates six categories for protected areas www.iucn.org/themes/wcpa/ppa/protectedareas.html.

IUCN Protected Area Management Categories I to IV cover areas designated for strict nature reserves and wilderness areas, national parks, national monuments, and habitat/species management areas. In IUCN Management Categories V and VI, exploration and mining may be acceptable where compatible with the objectives of the protected area and after environmental impact assessment. The activities should be subject to strict operating, monitoring and rehabilitation conditions.

IUCN and ICMM have agreed to work on the mining industries' participation and support for the process to further strengthen and apply the IUCN Protected Areas Management Categories System as a credible global standard.

In Australia, any development project is subject to national and state assessment if values of significance have been defined under the relevant legislation (refer to Further Reading and Websites Section for links). There are protected areas under both Federal and State legislation that may exclude mining and/or exploration activities in particular areas (for example national parks or marine parks).

Surveys by mining companies and others may occasionally reveal exceptionally high biodiversity values in areas that do not currently have legal protection. Detailed assessment of these values and the potential impacts of mining may indicate that the exclusion of mining activity is warranted.

CASE STUDY: Shelburne Bay – government and community action

Mining leases have been granted over areas later shown to be of significant conservation and biodiversity value, and whose sustainable conservation may be incompatible with proposed mining operations.

'No go' areas should be identified at the first stage of any project, and certainly prior to any disturbance. In the first instance, leading practice pre-mining biodiversity surveys, and effective impact assessment and mine planning procedures may raise environmental concerns. After discussion with government and other stakeholders in the area, a decision may be taken not to proceed with mining operations in that area.



Above: Shelburne Bay, Kerry Trapnell

Proactive government and community efforts are sometimes required to secure protection for those areas where values are not identified by a company during surveying or planning, or where information comes to light as a result of research undertaken independently of the mining company. Government involvement, as in the case of Shelburne Bay, may require special legislation to protect biodiversity and conservation values.

The dunefields of Shelburne Bay had been placed under mining lease for silica sand mining. The mining proposal would have involved the removal of two dune systems, Conical and Saddle Hills, near Round Point, Shelburne Bay, as well as the construction of a major port facility from the eastern end of Shelburne Bay via Rodney Island to deep water offshore.

Proposals to mine the area in the 1980s were overruled by the Commonwealth Government on the basis of the conservation value, however the dunefields remained technically available for mining operations. In 2003 the leases came up for renewal, but due to the concerns from Aboriginal groups, conservationists and members of the scientific community, the Queensland Government decided to cancel the leases when applications were made for their renewal.



The Government passed special amendments to the *(Queensland) Mineral Resources Act 1989* to confirm that the right of renewal of the leases was being revoked thereby ensuring the environmental and conservation values of the area are protected.

Left: Shelburne Bay, Kerry Trapnell

Gaps remain in the understanding and protection of many important species and communities, for example there is severe under-representation of freshwater ecosystems and marine ecosystems in the global protected area system. In many developing countries there are areas whose significance, in terms of biodiversity and related values, are still being documented or understood. Where communities' livelihood or culture is intimately related to a reliance on natural resources, the establishment of no-go zones for mining may, in some cases, be justified.

Making a decision not to explore an area regardless of its mineral prospectivity or its legal designation is, in some cases, a leading practice response. For example, this may be the case where there are gaps in knowledge or in representative protected areas, or where exceptional values are acknowledged but not yet legally protected. Alternatively, in taking a precautionary approach, some mining companies may choose to undertake further investigation and dialogue to determine specific details of any conservation values, potential impacts of exploration and mining operations. Investigation can also determine whether impacts can be managed and values restored, possibly in combination with an acceptable offset strategy. Application of leading practice technological and management approaches have increased the likelihood that minerals exploration can be undertaken in ecologically sensitive areas without compromising biodiversity and heritage values. In some instances, including Myall Lakes and Fraser Island, rehabilitated areas have been incorporated into conservation reserves following mining.

As discussed in the following sections, government, industry and community groups sometimes adopt strategic regional planning processes. This planning seeks to balance conflicting land use options including mineral activity, conservation and other land uses.

3.3 Landscape/catchment level planning

Planning at the landscape/catchment level assists in placing the proposed exploration and mining activities into a local and regional context. Landscape/catchment level planning enables leading practice mining companies to address both the direct and indirect impacts of their activities. It also helps determine the key components of biodiversity values at different scales including the representation of key elements in other areas. General aspects of planning are discussed below, while specific details of holistic land management are discussed in Section 4.1.

3.3.1 Regional planning

Where mining operations have many mines operating in a particular region, state governments can play a significant role in biodiversity management by setting up natural resource management plans. One such plan operates in the Hunter Valley of NSW.

The Synoptic Plan for Integrated Landscapes for Coal Mine Rehabilitation (DMR 1999) addresses progressive rehabilitation of all coal mines (open cut and underground), mine facility areas, established mine proposals and post mining sites within the Upper Hunter coalfield. The NSW Department of Mineral Resources (now Department of Primary Industries) led the plan's development. Its purpose is to provide the basis for a long term strategy for the rehabilitation of mines in the coal fields of the Upper Hunter Valley. The initiative encourages adjacent landowners, government and the broader community to contribute in planning and land management terms to a region wide landscape strategy.

The plan shows the status of mine development and rehabilitation at 1998. A second plan shows mine development at 2020. The 2020 plan conceptually proposes opportunities for revegetation across the coalfield in an integrated approach that considers biodiversity, agroforestry for amenity and commercial return, catchment protection and remodelling of mined landforms.

Another recent initiative increasingly used by managers to help focus on a regional landscape perspective involves the development of biodiversity action plans (BAP). These plans are usually based on the following hierarchical approach:

- avoid irreversible losses of biodiversity
- seek alternative solutions that reduce biodiversity losses
- use mitigation and rehabilitation to restore biodiversity resources
- compensate for unavoidable loss by providing substitutes of at least similar biodiversity value
- seek opportunities for enhancement.

The BAP is a structured approach for identifying priorities and mapping significant areas for native biodiversity conservation at the landscape and bioregional or biogeographical scales. The BAP attempts to take a strategic approach to conservation of threatened and declining species and assemblages, by looking for opportunities to conserve groups of species in appropriate ecosystems.

The development of a BAP by a mine operator depends on the location and type of operation. It may be at a local site level, on a slightly larger surrounding area or catchment level or may incorporate plans developed by governments or other stakeholders on a bioregional level.

3.3.2 Key role for government and other stakeholders in planning

As well as setting the broad regulatory framework governing mining activities, governments, together with the community, are now looking at a more regional approach to assessment and planning for biodiversity conservation. This is demonstrated in the nation-wide implementation of the National Action Plan for Salinity and Water Quality (NAP), the National Land and Water Resources Audit (NLWRA) and the Natural Heritage Trust (NHT).

Natural resource management (NRM) regions have been identified by the Australian, state and territory governments to facilitate natural resource management across Australia. Regional NRM Bodies (such as Catchment Management Authorities) prepare an integrated natural resource management plan for each region, identifying the priorities for on-ground action. Investments under NAP and the NHT are guided by accredited regional plans. Mining operators are tapping into these strategic plans, along with other land managers, to integrate biodiversity management on a larger scale.

Other organisations such as Australian Bush Heritage (www.bushheritage.asn.au) and The Nature Conservancy Australia (www.nature.org/wherewework/asiapacific/australia/) also have an important role to play in biodiversity conservation, and should be included/consulted during the planning process.

Biodiversity banking and offset schemes (BioBanking) are tools being developed by governments and stakeholders which provide systematic and consistent frameworks for counterbalancing (offsetting) the impacts of development. These tools seek to improve or maintain outcomes for biodiversity values (see also Section 4.3). The establishment of a BioBank site generates 'credits'. These credits can be sold and used to offset the impact of developments elsewhere. Funds generated by the sale can be used for management of the BioBank site (www.environment.nsw.gov.au/threatspec/infosheet.htm).

3.3.3 Cumulative impacts

Leading practice biodiversity management involves giving consideration to cumulative impacts during planning. The cumulative environmental impacts of a proposal on biodiversity are those impacts which are likely to combine with each other or with impacts of other activities to produce a beneficial or adverse effect. Impacts should be considered in terms of:

- the relationship of the activity to other proposals or developments in the area
- additive, synergistic or antagonistic effects of individual project impacts when considered in combination
- any known environmental stresses in the affected area and the likely contribution of the proposed activity to increasing or decreasing those stresses.

Advantages to addressing cumulative impacts over the lifecycle of a project can include developing relationships with local communities and regulators, and placing biodiversity values into context.

CASE STUDY: Junction Reefs – regional biodiversity enhancement

Junction Reefs Gold Mine incorporated regional biodiversity enhancement at a catchment level into its site rehabilitation strategy. The original vegetation of the NSW Central Tablelands was box woodland with an understorey of tall, warm season perennials such as *Themeda australis* (Kangaroo Grass). The early settlers viewed this as ideal for agriculture and converted them to farmland. Remnants are now restricted to small areas unsuitable for agriculture.

The Junction Reefs Mining Lease is bisected by a rocky ravine supporting a continuous band of remnant vegetation. Through the mine's rehabilitation program, a large conservation reserve was created in an area surrounded by degraded agricultural lands. This included 42 ha of mining affected areas and an adjoining 50 ha of remnant vegetation. Partnerships formed with the local community led to the enhancement of biodiversity values along the ravine and into the neighbouring catchment.

Before mining, the site was mostly degraded farm land. Through post-mining rehabilitation Junction Reefs Gold Mine intended to create eucalypt woodland with a grassy understorey, characteristic of the original woodlands prior to pastoral use. Dominant woodland species are often the focus of studies and rehabilitation strategies, however the native grassy understorey is often overlooked. Hand broadcasting of the local native species seeds onto



the weed-free oxidised subsoils resulted in variable, clumped and often high densities of trees, shrubs and grasses. The stratified layers of vegetation provide habitat for the local fauna. Many of the shrubs have reached maturity and regularly flower and set seed. The eucalypts also provide habitat for a variety of fauna species.

Left: Belubula River, Junction Reefs

In conjunction with Walli Limestone Landcare Group and Canobolas Parkland Trust, a stretch of river was restored as part of the Rivercare Incentive Scheme. This project linked the mine rehabilitation into the ravine and involved an ambitious plan to restore biodiversity by the removal of willow infestation, the main biodiversity threat to the riverine ecosystem. The banks of the river were then planted with local native riverine species. The willow removal improved stream bank integrity, thereby enhancing the aquatic ecosystem and its biodiversity.

On a broader scale, the Walli Limestone Creek Catchment Management Plan was developed through a partnership between the mine and local farmers. This led to corridors of native vegetation remnants being linked through farms and along water courses, using techniques and research developed for the mine revegetation.

Broadscale catchment management, combined with re-establishment of the river banks and their associated native vegetation cover complement the mine's rehabilitation. Overall enhancement of biodiversity values in the area led to the Junction Reefs Rivercare Project receiving the Gold Rivercare award from the NSW Government in 1998.

3.4 Risk assessment—identification of critical risks early, direct v indirect, precautionary principal

Risk assessment procedures need to be closely linked to the assessment of impacts (Section 3.5). This ensures that all relevant information is obtained and used in the decision-making process, with a view to optimising biodiversity management.

As discussed in Section 3.2, the mining industry has developed a range of risk assessment procedures that assist in defining potential 'fatal flaws' or 'no go' areas. In some instances, risk assessment can indicate that returns from the development of mineral resources may not outweigh the maintenance of the range of biodiversity values (for example, Mt Lesueur in Western Australia), the protection of a species or an ecosystem, or the protection of values that provide a significant cultural or production need for other sectors of the Australian community.

To minimise risks this assessment should be undertaken prior to any major commitment to intensive exploration or mining activities. Initially this assessment should be based on available datasets and a reconnaissance of the lease area(s) by experienced and qualified personnel. Initial discussions should then be held with experts and specialists in government agencies to review the sensitivity of the areas under consideration. An early review may assist all parties in delineating the risks associated with a particular area (for example, relic or restricted environments).

In areas where little is known about the biodiversity values it may be necessary to undertake some preliminary detailed work prior to ground disturbances to ensure that the risks to the project are minimised. The latter will require planning several years ahead to ensure sampling is undertaken by experienced and qualified scientists during the early phases of a project.

As an example at the state level, the Environmental Protection Authority in Western Australia Guidance Statement 51 (EPA 2004a) lists a variety of reasons why species, subspecies, varieties, hybrids and ecotypes may be significant other than as declared rare flora or priority flora. This guidance statement also gives reasons why plant communities or vegetation may be significant, other than their statutory listing as a threatened ecological community, or because the extent remaining is below a threshold level.

With regards to fauna, Environmental Protection Authority in Western Australia Guidance Statement 56 (EPA 2004b) provides useful direction and information on general standards and protocols for terrestrial fauna surveys. These standards and protocols can be used by environmental consultants and proponents engaged in environmental impact assessment (EIA) activities.

Generally, if any exploration or mining proposal poses a direct or indirect threat to a particular species or threatened ecological community that is listed (under state, federal or international legislation and agreements), then the significance of the values becomes paramount. Leading practice requires that, where there is a possibility of impacts, the following should be checked:

- species listed under the IUCN Red List of Threatened Species
- species listed under the Commonwealth EPBC Act
- state rare and threatened species listings
- other species of significance (for example range extensions, new species or taxon)
- Threatened Ecological Communities listed under the Commonwealth EPBC Act
- state threatened ecological community listings
- the Directory of Important Wetlands in Australia
- Ramsar listed wetlands
- wetland areas (in some states these are categorised on the current extent and condition)
- values at a range of scales from landscapes, ecosystems, plant communities, species;
- presence of threatening processes (for example feral animals, diseases, weeds) and the condition of the vegetation
- the Japan Australia Migratory Bird Agreement (JAMBA) and the China Australia Migratory Bird Agreement (CAMBA).

There has been an increasing emphasis on understanding the condition of the environment in exploration and mining areas, in relation to biodiversity conservation. Generally, if the system is degraded the significance of the biodiversity values in a particular area may be diminished.

Some ecosystems, although not currently listed as containing threatened species or communities, are particularly vulnerable to threats (for example, diseases such as *Phytophthora cinnamomi*). This characteristic needs to be given high priority in risk assessment and planning.

The precautionary principle, as defined in the *Environment Protection and Biodiversity Conservation Act 1999*, states that 'if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation'. The application of the precautionary principle to the management of biodiversity is a vitally important aspect of leading practice.

Where there is a lack of scientific certainty as to the impacts of a particular activity, for example insufficient baseline data on the biodiversity values of an area, or where there is uncertainty in relation to the capability of rehabilitation of particular ecosystems following mining, precautionary measures should be taken to avoid impacts. Depending on the gravity of the potential environmental loss, this may involve delaying the project cycle until further research including strategic regional assessments, analysis of cumulative impacts, or commissioning of additional baseline studies has been undertaken.

3.5 Assessing impacts to enable minimisation, mitigation and rehabilitation

Environmental and social impact assessment (ESIA) should be an iterative process of assessing impacts, considering alternatives, and comparing predicted impacts to the established baseline. At a minimum, the following assessments should be made in and around the proposed project area:

- an assessment of the impact level, (ecosystem, species and/or genetic)
- an assessment of the nature of the impact (primary, secondary, long term, short term, cumulative)
- an assessment of whether the impact is positive, negative or has no effect
- an assessment of the magnitude of the impact in relation to species/habitat richness, population sizes, habitat sizes, sensitivity of the ecosystem, and/or recurrent natural disturbances.

Many existing mining projects have conducted an ESIA some time ago, or in some cases, not at all. For these projects, it is important that biodiversity assessment and management considerations are built into their EMS and any other relevant internal and regulatory systems and procedures.

When assessing biodiversity impacts, it should be recognised that the intensity of impacts varies over the life of a project. Typically low at the start, the intensity of the impact increases markedly through the construction and operation phases and diminishes as planned closure occurs.

CASE STUDY: Community engagement to help conserve a significant species—the Glossy Black Cockatoo

The Glossy Black Cockatoo, *Calyptorhynchus lathami* is listed as 'threatened' under the Queensland Nature Conservation (Wildlife) Regulation, 1994. *C. lathami* is a large bird with a highly specialised diet. On Queensland's North Stradbroke Island, it has only been recorded feeding on two to three species of *Allocasuarina* trees, and is therefore very dependant on this food source. The trees were common in disturbed lands, and are now one of the more abundant tree species in developing rehabilitation following heavy mineral sands mining.

In pre-mining surveys conducted by Consolidated Rutile Limited (CRL), on North Stradbroke Island, a number of Glossy Black Cockatoos were discovered. They were found to be using the mine project area as both a feeding resource and for nesting. Feeding was taking place both within previously disturbed lands (historic mining and road easements) and in undisturbed areas. The largest evidence of feeding was within rehabilitation areas established in the late 1960s.

Faced with a fauna management challenge, CRL embarked on a program to survey the entire island for the presence of Glossy Black Cockatoos, to determine its conservation status across the several thousand hectares of potential habitat. Through the use of an



Above: Glossy black cockatoo, courtesy of Adrian Canaris, Biodiversity Assessment and Management (BAAM)

external consultancy and with help from volunteers from the community, the company surveyed the majority of areas both within and outside its lease areas.

Input from the local community enabled greater protection of this species within the region. The biological importance of specific areas often need to be considered at a regional level. Without the cooperation of local stakeholders, may be too time-consuming and costly for most mining companies to undertake.

The outcomes of the project have:

- provided the company with information to manage this species within its lease areas
- expanded the knowledge base by contributing to a much larger study of the species within the south east Queensland region, thereby helping to secure its future
- identified potential beneficial effects and opportunities for planting suitable food tree species for rehabilitation of mined land.

A proposed activity can directly or indirectly impact biodiversity. Both types of impacts need to be identified and managed. Other aspects or types of impacts also need to be considered. These are described in more detail in ICMM (2006) and include, but are not limited to, the following:

- cumulative impacts, as discussed in Section 3.3.3
- loss of ecosystem or habitats
- habitat fragmentation
- alteration of ecological processes
- pollution impacts. These can affect air, water and soil and can include:
 - airborne pollutants
 - water pollution from spillages or discharges and
 - mobile sediments from soil erosion
- disturbance impacts (soil disturbance, noise, vibration, artificial lighting)
- microclimate change affecting the suitability of sites for particular species.

3.6 Setting biodiversity objectives

As with land and water use objectives, biodiversity objectives should be developed in consultation with all stakeholders, and linked to specific, measurable targets and standards. They should form part of the completion criteria developed for the mine closure plan. Leading practice requires that these objectives be driven in part by the physical and biological components within the landscape, (recognising that mining may modify the physical components underpinning any rehabilitation). They should also be driven by the social and economic factors that are operating in the environment.

Further, there may be a need to delineate the project area into sub-areas, each of which differs in terms of the structural, physical, ecological, and social parameters that must be considered in sustainable mine closure planning. Each sub-area may differ in final land, water use or biodiversity objectives and appropriate closure measures. The objectives will depend on the biodiversity aspects identified, and the requirements and opportunities to mitigate impacts. They can focus on a specific local issue such as a plant or animal species, or they may be aimed more generally at the ecosystem level. In either case, objectives should be realistic and achievable and be set in conjunction with the biodiversity values identified by the company and stakeholders. All participants should seek opportunities to reduce negative impacts and increase positive impacts on biodiversity. Examples of goals and objectives may include:

- successful reintroduction of key flora or fauna species to mined areas
- non-disruption of migration/movement patterns
- protection (non-interference) of designated high conservation value sites
- control of weeds and other pest species.

Actions to achieve the nominated objectives should be developed and then documented within the EMS. Each mine should set specific, realistic targets that clearly describe what is to be achieved and by when, and that are linked into the overall rehabilitation and mine closure strategy. Each target should take into account availability of resources, any technical limitations, the expertise of personnel and contractors, views of landowners and the community, as well as long-term land management requirements.

3.7 Planning for closure

Conservation and sustainable management of biodiversity values during mine closure planning is an ongoing process. Leading practice requires that this planning start from the earliest moments of project planning and development, and continue throughout the life of an operation. Leading practice also requires open and effective dialogue with regulators, the local community, indigenous groups and traditional owners, conservation NGOs, and any other stakeholders. Mine closure and decommissioning plans are dynamic documents that may need to be adjusted and updated in response to:

- changing stakeholder expectations
- variations in regulatory requirements
- shifts and changes in the nature of the project
- findings from monitoring programs and supporting investigations, for example new information on environmental values that require restoration or reintroduction
- improvements in rehabilitation technology and industry practice.

General requirements for developing a mine closure and decommissioning plans are discussed in the *Leading Practice Handbook on Mine Closure*. The plan should cover key biodiversity aspects with regards to:

- baseline conditions
- predicted impacts of the operation
- the physical extent of impacts associated with operations
- the operational plan
- agreed end-use for the various components
- future ownership and maintenance.

The baseline sets the 'terms of reference' for decommissioning planning. It should clearly define biodiversity values of the receiving environment and the project's potential impacts. It also defines the decommissioning requirements arising from legal or regulatory controls, and the expectations of other stakeholders in regard to decommissioning outcomes.

Regular review of the closure and decommissioning plans should identify knowledge gaps relevant to biodiversity management and conservation. These may include information gaps, potential issues or risks and ongoing monitoring, investigation, and research needs. All operations require some flexibility in the planning phases as priorities and operational activities evolve. There are associated potential direct and indirect impacts associated with these changes.

CASE STUDY: Taking biodiversity into account in mine closure–Timbarra Gold Mine

Barrick Australia's Timbarra Gold Mine is located east of Tenterfield in northern NSW. Operations started in April 1998 and the mine was placed under care and maintenance in October 1999. Activities since then have focused on mine closure and associated rehabilitation and monitoring requirements.

The 82 ha disturbed during the mine's operation included two pits, a spent ore stockpile, water storages and processing plant, ROM pad and haul roads. For the purposes of rehabilitation, these areas were treated as separate domains.

A selection of native species including ground, mid- and upper layer species were planted as part of the rehabilitation program. Where practical revegetated landforms were made contiguous with the surrounding environment.

The primary aim of revegetation was to re-establish the majority of target vegetation consistent with the seven natural vegetation communities that occurred in the area disturbed. These communities broadly fall into three categories– forest, woodland and sedgeland – that in general terms the rehabilitation will establish. Species selection has taken into account their occurrence in each of these categories. Selection has also considered locally significant species, those that provide:

- habitat and resources for fauna
- dominant species
- those that assist in maintaining surface stability and,
- those that provide suitable seed or plant material for propagation.

The creation of habitat for significant fauna species such as the Glossy Black Cockatoo, Hastings River Mouse and Rufous Bettong was an important consideration in the design of the rehabilitation program. Habitat creation plans that identify designated habitat creation areas across the site were developed. Sketches aided implementation of key commitments provided in earlier environmental assessment documents. The sketches include general locations of habitat creation initiatives such as revegetation with selected native plant species, boulder piles and logs, and habitat creation for significant species such as the Rufous Bettong.

Suitable habitat for the Rufous Bettong typically includes eucalypt forests, wet sclerophyll forests to low dry open woodland areas with sparse or grassy understorey. Grassy understorey species including *Imperata cylindrica*, *Entolasia stricta*, *Austrostipa pubescens* and *Themeda australis* were recorded during monitoring. Areas within the woodland designated areas have been targeted for sowing a grassy understorey of these species. It is expected that the proposed understorey will provide habitat for the Rufous Bettong.



Above: Habitat corridor, Timbarra Gold Mine

Conservation and sustainable management of biodiversity values is an ongoing process. Following mine closure and lease relinquishment, all rehabilitated mined land and watercourses will require management and, for a period, monitoring. The closure and decommissioning plan must therefore include workable solutions to post-closure management and monitoring issues, The plan should clearly define roles and responsibilities, and identify sources of funding for ongoing management costs. Current or new partnerships can help ensure the sustainability of existing and restored biodiversity values. Caveats may be required to ensure that the subsequent landowner is committed to sustainable management of the area's environmental, social and economic values. Species recovery plans, for example, can extend beyond the life of the mine.

Development of completion criteria to determine whether key biodiversity objectives have been met is discussed in Section 5.



4.0 INTEGRATED BIODIVERSITY MANAGEMENT

KEY MESSAGES

- Management of biodiversity impacts due to mining should involve, in order of priority: *avoid - reduce - remedy (or mitigate, restore, revegetate) - compensate (offsets)*. This approach is now adopted in most ESIA planning processes.
- Biodiversity values transcend boundaries imposed by man. For this reason, it is important that a holistic view is taken when managing biodiversity.
- It is important to minimise impacts on the floral and faunal communities of surrounding areas in order to achieve mine rehabilitation objectives.
- Offset schemes are gradually being incorporated into the ESIA process, and should be considered where appropriate.
- Community partnerships are an effective means of achieving mutually beneficial conservation outcomes.
- Leading practice management of water quality goes beyond compliance and focuses on understanding and managing biodiversity values of the receiving environment.
- Feral fauna species, weeds and plant pathogens need to be monitored and their impacts understood and managed. They can significantly reduce an area's biodiversity values, and retard development of the post-mining rehabilitated ecosystem.
- Where re-establishment of biodiversity is a priority, this should be taken into account during all stages of the operation, including topsoil management, seeding, planting and where required, establishment of recalcitrant and rare species, and habitat transfer.
- Restoring fauna habitat may require the use of specialised techniques for particular species.

Leading practice biodiversity management requires the high standards of assessment and planning that are described in Section 3. These need to be incorporated into the mine's day-to-day operations, across all stages from exploration to mine closure. Guidance documentation ranging from an overarching EMS and associated environmental management plans (EMP's) to specific work instructions with a focus on biodiversity management need to be developed and implemented. Leading practice biodiversity management now involves taking into account much broader whole-of-lease aspects rather than simply focussing on the area of direct impact and areas immediately adjacent. Companies are now seeking and implementing opportunities for biodiversity conservation and rehabilitation, often in partnership with community groups, as part of their sustainable development approach.

Companies wishing to adopt leading practice biodiversity management standards have a range of options available to them for the management of biodiversity impacts in mining situations. The hierarchy of biodiversity risk management - *avoid - reduce - remedy (or mitigate) - compensate* - as discussed below, is now adopted in most ESIA planning processes. The management of biodiversity impacts involves identifying measures that safeguard biodiversity values that may be affected by the proposed project. The mitigation measures identified during ESIA, should be incorporated into an Environmental Management Plan and implemented upon project commencement.

Avoid impacts

Potential impacts on significant sites may be avoided by selecting an alternative location for associated infrastructure. Locating processing works within a nil discharge catchment, for example, may reduce the potential for pollution of streams. Alternative treatment or processing routes such as cyanide recovery or destruction technologies may be used to avoid the potential for high cyanide concentrations in dams affecting wildlife.

Reduce impacts

Where the impact of mining operations cannot be avoided, it may be possible to minimise the impact of the operation by modifying project design or layout. This can reduce the area of influence and the duration of the impact. Adopting high standards of quality control and monitoring can also contribute to impact minimisation.

Remedy impacts

Impacted areas may be restored by using the rehabilitation and revegetation techniques described in Section 4.7.

Compensate impacts

Offsets are activities undertaken to compensate the impact of an action where impacts are unavoidable. They are discussed in more detail in Section 4.3, and also in ICMM (2005a,b).

Effective management of contractors is also an essential aspect of leading practice biodiversity management. Increasingly, strict obligations are placed on construction companies to implement their own EMS to deliver to the mine owner's standards, including:

- the protection of vegetation and watercourses (no clearing outside designated areas)
- the control of pests (no pets, wash down of all vehicles)
- disruption of wildlife (for example, restricted access to areas)
- waste management.

Leading practice mining companies evaluate construction contracts on the basis of the contractor's past performance and audits of the contractor's environmental management programs, systems and performance.

4.1 Holistic land management

Holistic land management involves the integration of the mining area within the broader landscape. In contrast to the normal focus on the direct, on-site impacts of operations, holistic land management also emphasises the management of lease areas not directly disturbed by mining and mineral processing activities.

Biodiversity values transcend boundaries imposed by man, such as mining leases, land tenure, and conservation reserves. Examples of biodiversity values that may overlap boundaries include:

- watercourses
- corridors connecting areas of remnant vegetation
- soil types supporting particular vegetation communities
- the home ranges of many fauna species, as well as migratory species.

It is therefore important to take a holistic view when managing biodiversity. Where possible, mines should liaise with adjacent landowners and community groups to define conservation values. Cost-effective means of minimising impacts can then be developed. Reinstating values affected by previous degradation or through unavoidable impacts of the mining operation should also be considered where practical. Leading practice companies are using this approach as part of a whole-of-lease perspective, and in some cases, a regional perspective with respect to biodiversity management.

Opportunities often exist for integrating conservation management practices on the mining lease with other local and regional initiatives. Examples include the New South Wales Hunter Valley Synoptic Plan (NSW Department of Mineral Resources 1999) and the Glennies Creek Catchment Total Catchment Management Study (Hunter Catchment Trust 2003).

Often government requires the development of landscape level planning, with careful consideration of threatened species management, as a requirement for project approval. Forging partnership with government can therefore improve the effectiveness of on-site management.

A holistic landscape approach to biodiversity management is equally important when managing indirect impacts such as pest plants and animals. More detailed aspects of this are discussed in Section 4.6. Identifying pathways species use to move across the landscape, and concentrating efforts on preventing re-colonisation, will greatly increase the effectiveness of control efforts and reduce the ongoing cost of control.

4.2 Maintaining ecological services

The maintenance of ecological services should be a key aim of on-site biodiversity management. Services such as habitat for threatened species, water quality and natural pest control (for example, by insectivorous birds) should be maintained until the site can be rehabilitated.

Options considered when planning the maintenance of ecological services should account for a species' ability to adapt to such changing factors as climate and environments.

Mining operations commonly involve a high level of disturbance over a limited area. Ensuring the continuation of ecological services presents a challenge, as they can often be strongly linked to site, and may not be readily delivered in other locations. Solutions to this can include the maintenance of 'bridging habitat' through conservation covenants or other agreements with neighbouring landholders, or incorporating specific habitats into progressive rehabilitation programs during the life of mine.

4.3 Biodiversity offsets

Biodiversity offsets are the 'conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure no net loss of biodiversity (ten Kate et al.2004). Before developers contemplate offsets, they should first seek to avoid and minimise harm to biodiversity. A number of other key references (for example ICMM 2005a,b, Baird 2003, NSW EPA 2002, EPA 2006, and Rio Tinto 2004) strongly emphasise the importance of addressing impacts in the following sequence: Assess, Avoid, Minimise, Mitigate (for example Rehabilitate or Restore). Only when this process has been exhausted should offsets be considered.

Despite the presence of developmental problems, such as how to measure biodiversity loss or gain, more planners are including offset schemes into the ESIA process. It is being increasingly recognised that a well designed and transparent offset system can play an important role in ESIA, resulting in sustainable development and better environmental outcomes.

There are two types of environmental offsets as defined in the Western Australian EPA Position Statement No. 9 (2006):

- 'no net loss' aims to balance environmental loss with environmental gain, creating no overall significant environmental difference. It refers to no overall loss of the total extent, quality, ecological integrity and security of environmental assets and their values
- 'net benefit', or net gain, aims to ensure more environmental gains occur than environmental losses. It refers to an overall improvement in the total extent, quality, ecological integrity and security of environmental assets and their values.

Whether a mining company chooses to aim for no 'net loss', or 'net gain', will depend on government regulatory requirements, the company's policy, and in some cases the views of key stakeholders. Rio Tinto's net positive impact policy, and BHP Billiton's sustainable development policy's aspirational goal of zero environmental harm are examples of environmental offset initiatives. The state governments of Western Australia, South Australia, Victoria, Queensland and New South Wales require offsets to compensate for unavoidable clearing of vegetation.

There are a variety of offset options, depending on the impact. Offsets, for example, can be designed to compensate for:

- the area of impact
- quality, for example, forest quality
- conservation/economic value of an asset
- impacts on species
- impacts on habitat value/status
- ecological integrity
- ecological function
- security of tenure and management.

Offset mechanisms that can be used to address impacts include rehabilitation of existing degraded ecosystems, re-establishing desirable ecosystems (for example re-establishing biodiversity corridors or specific ecosystems in areas of low representation) or implementation of agreed recovery plans for species. Where native vegetation is outside the conservation estate and is subject to threatening processes, its acquisition and inclusion into the conservation estate may be considered an offset. Other offset options include:

- contribution to knowledge through monitoring and research
- provision of resources for local conservation or Landcare groups
- fencing of remnant vegetation
- preparation of management plans.

Whichever option a company chooses to adopt, stakeholder consensus is usually required to determine what constitutes no net loss (or net gain) and how a balance between the impact and offset can be achieved.

Conservation banking provides a mechanism for the restoration, enhancement, conservation or creation of habitat, principally through the establishment of 'banks' in advance of anticipated losses. Sites are chosen and managed for their natural resource values and special-status species or sensitive habitats to earn 'credits'. Within Australia, conservation banking as means of preventing loss of biodiversity is in developmental stage with limited use in Victoria and New South Wales. It is recommended that mining companies keep abreast of obligations and opportunities as they continue to develop.

Conservation banking has the advantage of providing concurrent offsets while developmental impacts occur. Alternatives often require waiting several years before rehabilitation of vegetation community occurs and recolonised by fauna. This also brings the risk that rehabilitation may not develop as expected. Conservation banking can offer a wider range of offset options for regulators and stakeholders to consider while offering landowners incentives to conserve and restore degraded habitats on their land.

4.4 Building community partnerships

A comprehensive program of community engagement is an essential component of modern mining and minerals processing operations, and in maintaining and enhancing the industry's social licence to operate. In addition to endorsement and support for biodiversity management on a site, community groups can be a valuable resource for the mining industry. This is particularly the case for those indigenous communities, who are custodians of traditional knowledge regarding the spiritual, social and ecological importance of biodiversity within an area.

Many mining companies have developed ongoing associations with traditional owners in the areas in which they operate. Indigenous communities at a range of mining sites are involved with the definition of and assessment of biodiversity values. The local indigenous communities have continued to use the biodiversity values in terrestrial and marine systems for hunting and gathering food, recreational activities and cultural ceremonies.

A range of strategies designed to maximise the protection of key components of the environment have evolved from relationships between indigenous communities and mining companies. Methods of enhancing and improving rehabilitation techniques in consultation with local indigenous people and researchers have also been developed. Input from indigenous knowledge include:

- identification and documentation of the cultural, practical, medical and food significance of native species
- participation in the definition and assessment of biodiversity values at different scales (for hunting and gathering food, recreational and traditional activities and cultural ceremonies)
- identification of key biodiversity values during exploration activities
- definition of suitable species mix and proportion of species suitable for rehabilitation areas.

Specific guidance on working with indigenous and other communities is contained within the Leading Practice - *Community Engagement and Development* and *Working with Indigenous Communities* handbooks.

Implementation and monitoring of environmental planning should be viewed as more than a regulatory imperative. Local communities represent an important resource for the design and implementation of rehabilitation and offsetting works. This is particularly the case where local indigenous communities have maintained their traditional knowledge base and connection to the land. It is critical for companies that are focused on habitat creation and restoration as part of offsetting arrangements to understand the ecological interactions that characterised the pre-disturbance landscape. Without this knowledge, planning may exclude keystone components of the ecosystem, compromising the ability of the rehabilitation or offset areas to either establish or be self-sustaining.

Increasingly leading practice companies are going beyond consultation to develop mutually beneficial partnerships with local communities, to deliver rehabilitation and environmental restoration works. Transparency and open disclosure of biodiversity policies, management systems and outcomes is an important aspect of building relationships of trust with local communities and other stakeholders. Mutually beneficial partnerships that provide environmental, social and economic dividends can be created. Local communities, for example, have skills in local seed collection and other services.

In addition to engaging with local communities, many companies are developing partnerships with global and national conservation NGOs. Such partnerships enable the industry to better identify and work to address issues of mutual interest and concern. By partnering with environmental and conservation NGOs, the industry can gain access to specialist skills, expertise and collaborative networks on biodiversity conservation issues. From the NGO perspective, partnering not only provides access to financial resources but enables the NGO to work in a collaborative way with industry on key biodiversity issues. For example, for the past seven years, Rio Tinto has had an active and dynamic biodiversity partnership program with organisations such as Birdlife International, Fauna and Flora International, and the Royal Botanic Gardens Kew Millennium Seed Bank Project. Initially set up to help Rio Tinto develop its biodiversity strategy, the partnership program is now playing a leading role in the development and delivery of biodiversity programs at sites in Australia and elsewhere.

CASE STUDY: Effective partnerships promote threatened fauna recovery—Arid Recovery

Right: Arid recovery fence to exclude non-native mammals, BHP Billiton

Arid Recovery is an ongoing ecosystem restoration partnership established in 1997 between WMC Resources (subsequently acquired by BHP Billiton), the South Australian Department for Environment and Heritage, the University of Adelaide and the community group Friends of Arid Recovery. From the outset, the partners agreed on the following as their aims:

- to facilitate the ecological restoration of arid ecosystems
- to provide transferable knowledge, information and technology for broadscale environmental management of Australia's arid lands
- to apply the principles developed to demonstrate how mining, pastoralism, tourism and conservation organisations can work together to achieve tangible benefits from sustainable ecological outcomes.



The program, located near the Olympic Dam mine, started with the creation of a 1400 ha reserve fenced to exclude non-native mammals such as feral cats, rabbits and foxes that threaten the area's conservation values. After four expansions, the protected, fenced area now covers 8600 ha.

All feral cats, rabbits and foxes were eradicated from the reserve after thousands of hours of work by staff, students and volunteer labour. This created a protected area where four locally extinct species were successfully reintroduced, namely the Greater Stick Nest Rat, the Burrowing Bettong, the Greater Bilby and the Western Barred Bandicoot. All four species are now living and breeding within the reserve. Numbats have been released on trial and Woma Pythons will also soon be reintroduced as part of Arid Recovery's plan to recreate a self-sustaining and functioning ecosystem within the reserve.



Above: Burrowing Bettong, BHP Billiton

Several native species have increased in numbers within the fenced area. There are now up to 10 times as many small mammals inside the reserve as there are outside. A comprehensive plant monitoring program has also demonstrated considerable recovery of the reserve's natural vegetation. Arid Recovery is now applying research outcomes into reintroduction techniques

and broadscale predator control to introduce free-ranging bilbies onto the Olympic Dam mine lease and adjacent pastoral stations. The program now provides opportunities for staff, university students, visiting scientists and volunteer teams to study the responses of plants and animals to the removal of feral animals and reintroduction of native species. Arid Recovery demonstrates the potential for biodiversity gains from multi-stakeholder partnerships.

4.5 Managing impacts

Mining projects and associated mineral processing facilities can impact on biodiversity in a variety of ways, including but not limited to:

- direct impacts on terrestrial vegetation and fauna through clearing and habitat fragmentation for mining and associated infrastructure
- impacts on aquatic ecosystems and groundwater dependent ecosystems through hydrological, geomorphological and water quality changes
- impacts on adjacent ecosystems due to noise, dust and other atmospheric emissions (for example, from mineral processing facilities)
- impacts due to wildlife contacting hazards and hazardous materials, including caustic and cyanide containing tailings storage facilities and power lines

- impacts on adjacent ecosystems due to changes in land use, for example changes in grazing patterns and fire frequency, introduction of weeds and plant diseases or changes in feral fauna abundance
- other impacts, for example, changes to the extent of hunting, fishing, wood gathering, introduction of pets (dogs and cats), road kills of native species, and disturbance by off-road recreation vehicles.

The following briefly discusses ways companies are managing the extent of these impacts on biodiversity values. In most cases there is a common theme of identifying the impact, monitoring its extent, then developing and implementing strategies for avoiding, minimising and mitigating (for example, through rehabilitation of disturbed areas) its effect. All of this forms an important component of an ISO 14001 compatible EMS.

4.5.1 Day-to-day site operations

While the process of mining will always involve some impact in a localised area, there are a variety of measures that companies can take to reduce impacts within the site, and ensure that other impacts are contained to areas under direct control. It is common practice for mining operations to develop an environmental management plan (as part of their overall EMS). This plan lists all significant environmental values on the site, identifies risks to these values, and appropriate actions to manage the risks. A risk-based approach to environmental management and planning can ensure that resources are consistently directed to addressing the most critical risks to biodiversity.

While almost all aspects of mining operations can potentially impact on biodiversity and need to be considered as part of the site EMS, the following should be specifically noted.

Site water balance

Any EMS needs to detail both the extraction and release of water. As described in Section 4.5.3, the EMS should not only address managing impacts relating to the quantity and quality of water movements, but should also give consideration to the timing of these releases. Several Australian ecosystems rely heavily on particular flow cycles for breeding events and flushing. Disrupting these and/or replacing them with a different cycle can detrimentally affect some native species and favour introduced species.

Vegetation

Regulators and other stakeholders are often keenly interested in the clearance of vegetation and the management of uncleared areas within the mine site (discussed in section 4.5.2). The EMS should also consider the connectivity of the remnant vegetation on the site to vegetation in surrounding areas. This is important as native and introduced animal species both use remnant vegetation as cover when moving across the landscape.

Infrastructure

The development of linear infrastructure such as roads, pipelines and overland conveyers associated with mining projects can impact on a wide range of ecosystems. Disturbance of habitats can occur during construction, Ongoing impacts can also result, such as barriers to wildlife movement, road kills and water pollution from runoff. The movement of animals across the landscape is not uniform. Identifying favoured crossing points and installing under infrastructure access, road signage, speed limits, rumble strips or other measures can greatly reduce wildlife impacts.

Good housekeeping

Good housekeeping is one of the easiest and most cost-effective strategies for avoiding impacts on biodiversity from pollution. For example, on sites where hydrocarbons, processing chemicals, or any other hazardous materials are stored or used, strict adherence to all safety and materials handling guidelines should minimise the chances of spills and any other accidents or incidents occurring.

In summary the impacts of day-to-day site operations on biodiversity need to be clearly identified, and procedures and systems put in place to avoid or minimise their effects.

4.5.2 Managing impacts on terrestrial vegetation and fauna

The first step to minimising direct impacts on vegetation and associated faunal communities is to identify the location of values from survey information. From this environmental management plans can be developed and implemented to ensure that, where possible, high value areas are not cleared. In all instances, these plans should ensure that the extent of clearing is minimised, consistent with the safe and efficient operation of the mine. The extent of suitable habitat and its connectivity should allow for the mobility of most fauna species. Successional aspects are also important. For example, inappropriate fire regimes can affect all of a remnant area within a mining lease resulting in the loss of certain species. Rapid rehabilitation of disturbed areas can minimise the impacts of habitat fragmentation.

Even in instances where rare or threatened fauna species are no longer present in an area, if surveys show the habitat to be either formerly occupied by the species, or suitable, then it should be managed accordingly, since it is possible that the species may colonise (when threatening process such as fox predation are removed or reduced), or be reintroduced at some later stage.

Secondary impacts such as changes in grazing patterns and the introduction or increases in weeds and feral fauna, should be addressed by the development and implementation of land management plans. Identification and control of problem weeds, including the prevention of introduction in and adjacent to operating areas, should be carried out. Where feral fauna such as the fox, cat, pig or goat are negatively impacting conservation values, their numbers should be monitored and if necessary, control methods implemented.

Leading practice biodiversity management goes beyond minimising long-term impacts from operations. It identifies opportunities for improvement in the lease and adjacent areas by:

- introducing innovative and sustainable land management practices
- controlling weeds and feral fauna to the greatest practicable extent.

These initiatives may be undertaken by the companies themselves, or in partnership with government and NGOs.

CASE STUDY: Rehabilitation of dieback affected areas in jarrah forest

In the jarrah forest of Western Australia a plant disease (dieback) caused by the introduced soil-borne pathogen *Phytophthora cinnamomi*, can lead to severe degradation in the most susceptible sites. Many of the dominant jarrah species (*Eucalyptus marginata*) are killed in these infested areas, along with a range of mid-storey and understorey plants. This can result in significant impacts on the biodiversity values of severely affected areas. Alcoa's bauxite mining operations occur in the jarrah forest and degraded sites are present within the mine envelope. In 1979 the company made a commitment to support a rehabilitation program for these sites within the mine envelopes of its three mines.

Operational procedures are funded by Alcoa and generally conducted by the Department of Environment and Conservation (DEC), the state government department that manages the forest. The annual works programs are jointly planned by Alcoa and DEC. The overall objective of the program is to rehabilitate forest degraded by dieback, improving the potential of the forest to meet the designated land use objectives. The specific land use objectives are to increase biodiversity by using sustainable forest management practices, maintain potable water quality and improve aesthetics. Only local trees and local understorey plants are re-established.

Alcoa is also working in partnership with DEC and Murdoch University to identify and propagate dieback resistant jarrah plants to be used in these areas. The program is called the Dieback Forest Rehabilitation program and it continues to be maintained and supported by Alcoa and DEC. To date, more than 3000 ha have been treated in this ongoing program.

This successful partnership between industry research groups and the State Government led to the improvement of degraded vegetation communities around the mining area.



Left: Dieback Rehabilitated Area, Alcoa

Tailings facilities can pose a threat to species and communities. The extent of the threat depends on their location, concentration of the hazardous materials (such as cyanide or caustic soda), the species present, and the design of the facility. If the likelihood of impacts is found to be high, the facility should be designed to make it 'unattractive' to wildlife and to ensure that problems can be managed, should they arise. Specific threats associated with tailings storage facilities are discussed in the *Leading Practice Handbook on Tailings Management*.

4.5.3 Managing impacts on aquatic fauna

Principles noted (4.5.2) for terrestrial ecosystems are also relevant to managing impacts on aquatic ecosystems. Aquatic ecosystems occupy low-lying parts of the landscape and will, therefore, be the ultimate recipients of runoff from mining activities. The linkages between the quality of terrestrial ecosystem management and receiving aquatic ecosystems are typically very strong. It is therefore difficult to achieve good outcomes from planning management of aquatic ecosystems without due consideration of these linkages.

Mining impacts on aquatic ecosystems arise from four sources:

- water quantity issues
- water quality issues
- habitat structure issues and
- organism passage issues.

Alterations of the surface runoff and/or groundwater flow characteristics and pathways can affect water quantity. Mined landscapes can differ greatly in rainfall-runoff relationships from the original landscape. Rehabilitated landscapes will commonly have altered topography from the original landform, resulting in changes to the directions, quantities and timing of surface flows.

Furthermore, mines often intercept or use aquifers. The geological layers mined may themselves be important aquifers supporting groundwater dependent ecosystems. In the arid and semi-arid regions that host much of the Australian mining industry, ground waters are commonly key resources used by mining companies. The impacts on these ecosystems during and post operation need to be understood as do mechanisms for their maintenance and rehabilitation.

The ANZECC/ARMCANZ (2000) Water Quality Guidelines summarised in Batley et al.(2003) together with associated state and territory legislation, constitute a water quality risk-management framework for management of biodiversity in aquatic ecosystems.

Leading practice management of water quality impacts follows the risk-management framework of the guidelines. It should also ensure the monitoring program sensitivity can detect trends in water quality parameters while the measurements remain below the water quality objectives. This allows management steps to be implemented before a declining trend of water quality can lead to biodiversity impacts.

Leading practice management of water quality should also include management and monitoring of process reagents, solid and liquid wastes (including domestic wastes), hydrocarbons, degreasers and sewage effluents. These aspects can be particularly important during periods of high rainfall, when it may be difficult to retain all surface and groundwater runoff from mining-related infrastructure, including contractor sites.

The water quality guidelines do not fully address the difficulties associated with their application to temporary waters. In particular, the trigger values contained in the guidelines are based on steady-state conditions, that by definition, do not occur in temporary waters; there are no toxicity-based trigger values provided for inland salt lakes; and the recommended biological water quality assessment strategies are untested for mining impacts in all but a few types of temporary waters. This limits their use in the arid and semi-arid zones of Australia, where temporary waters dominate, and where the majority of mining occurs. An Australian Centre for Minerals Extension and Research project (Smith et al. 2004) reviewed current practices and potential mechanisms to improve water quality assessment for temporary waters relevant to the mining industry. Such assessment is essential if high standards of adaptive management are to be achieved.

Habitat structure in aquatic ecosystems is a major controlling factor of biodiversity. Sedimentation of stream beds, pools and backwaters can result in reduced biodiversity due to the reduction in the available niches. Stream diversions that do not match the pre-existing habitat structural diversity will be unlikely to support the original aquatic biodiversity. This may affect biodiversity upstream and downstream of the diversion by alteration of organism passage and reach-scale ecosystem energy flow. Leading practice managers design compensatory habitat structures into the diversion, such as planting additional overhanging reeds, rushes and shrubs and constructing natural or above natural densities of large woody debris structures. The engineering design of the diversion should account for the increased hydraulic roughness associated with these structures..

Alteration of the landscape caused by mining that results in altered flow paths and velocities of surface and ground waters will result in altered geomorphic influence on the receiving aquatic ecosystems. The resultant impacts on aquatic habitat structure and the biodiversity dependent upon it need to be considered.

CASE STUDY: Significant species management as a surrogate for ecosystem protection—pygmy perch

In 2000, the Oxleyan Pygmy Perch (*Nannoperca oxleyana*), listed as 'endangered' under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 and 'vulnerable' under the Nature Conservation Regulation 1994 (Qld), was found at Little Canalpin Creek.



Above: Male Pygmy Perch, CRL

Little Canalpin Creek is located adjacent to one of Consolidated Rutile Limited's (CRL) heavy mineral sand mines, on North Stradbroke Island in Queensland. The dredge path for this mine was to travel adjacent to this wetland, often at times less than a kilometre away. The creek and its catchment were within the lease but were not to be disturbed due to their high ecological values.

A risk assessment showed that there was a high initial risk of disturbance to the species' habitat. CRL therefore prepared a Significant Species (Fish) Management Plan for the Oxleyan Pygmy Perch. Protection of the environmental requirements of this species was deemed to involve protection for the entire Little Canalpin Creek ecosystem.

Detailed modelling of groundwater and perched aquifer layers using drilling data enabled the mine planners to determine a minepath that minimised the disruption of the perched catchment of Little Canalpin Creek. This also reduced the potential for increased mine water impacts during the dredging and tailings management phases. Water management infrastructure was installed to combat any changes to water flow in the creek.

CRL minimised disturbance in the catchment, whilst at the same time initiating a complex water-monitoring program and undertaking regular biological health assessments of the area. A captive breeding facility was established in February 2001 to safeguard the species should a catastrophic failure occur. The successful breeding program has been expanded to include research into the species and its survival. This has led to a greater understanding of the Oxleyan Pygmy Perch and assisted the government in developing a recovery plan for the species.

Where feral species are present, special measures are sometimes needed to prevent dominance of feral populations and to assist recovery of native populations. These measures, including enhanced stocking of native species and/or feral species control measures, can be needed in addition to leading practice aquatic habitat management.

Impediment of organism passage, particularly of fish, is often a greater consideration for Australasian aquatic ecosystems than other parts of the world. Few Australian native fish species can jump over obstacles, or traverse stream sections with flow velocities above 1 m.s⁻¹. Blocking sunlight from the water surface for more than a short distance can also impede fish movement. Where appropriate using large diameter box-culverts with natural substrate lining should be considered to facilitate passage.

When seeking to minimise impacts to organism passage, recommended passage design standards for Australasian species can be used for the design of physical structures.

4.5.4 Managing impacts on aquatic, riparian and groundwater dependent vegetation

Light is a key requirement for aquatic vegetation. Mining can both reduce and enhance the amount of light received by aquatic ecosystems. Light reductions are generally related to increased turbidity. Light enhancement can occur via alteration of bank profiles or removal of riparian vegetation. Any alteration of the light regime of an aquatic ecosystem can affect the selective pressures on the flora, and potentially alter the resident floristic biodiversity. Increased light can lead to algal blooms (if the nutrient availability permits) or enhanced macrophyte growth over the natural levels, while increased turbidity can inhibit growth of some species, but favour low-light tolerant species. Either change can result in reduced biodiversity by favouring a subset of the resident species or excluding a subset of species.

Alteration of the biodiversity and structure of floral assemblages in aquatic ecosystems will also affect habitat structure and the food web. Aquatic plants form both habitats and food resources for many aquatic animals, and are therefore primary determinants of many aspects of the ecosystem structure and dynamics.

For these reasons, leading practice requires that mining companies take steps to understand and manage any impacts their operation may have on aquatic vegetation.

A range of vegetation communities are dependent on the hydrology and water quality of streams, rivers, lakes, and groundwater. These include:

- aquatic species that grow in the water itself (for example *Potamogeton spp.*)
- riparian species such as rushes, sedges, and shrubs and trees growing adjacent to watercourses (commonly *Melaleuca spp.*, River Red Gum *Eucalyptus camaldulensis*)
- phreatophytic, or groundwater dependent vegetation (for example Coolibah *E. victrix* and many other species).

The latter are part of what are becoming recognised as groundwater dependent ecosystems. Changes to hydrology and water quality can impact on these vegetation communities and species. Examples of this include:

- pumping of water from mine dewatering operations into existing watercourses, with increased flows resulting in impacts on riparian vegetation including nearby trees
- dewatering and release of saline groundwater can impact on riparian vegetation and species adjacent to watercourses
- diversion or damming of streams, or use of water for mine operations will decrease stream flows and can result in impacts on vegetation as above
- mine dewatering operations lowering the groundwater table, resulting in effects on phreatophytic (groundwater dependent) vegetation
- other changes in groundwater hydrology and associated hydrological cycles, caused by landform changes resulting from mining operations - these too can result in impacts on those phreatophytic vegetation species that have specific requirements
- accumulation of silt due to erosion associated with mining operations, affecting vegetation health in areas where the silt is deposited
- changes to water quality, including elevated metals concentrations, and acid rock drainage (ARD), with resulting impacts on riparian and phreatophytic vegetation
- tailings storage facilities can result in local changes in hydrology or, if the containment is not effective, can change groundwater quality with impacts on vegetation
- Interruption of surface water flows through the development of infrastructure facilities.

These examples illustrate that a range of mining-induced changes to hydrology and water quality can result in impacts on vegetation. These can include changes in the relative abundance and distribution of species, alteration of vegetation communities, increased susceptibility to weed invasion, impacts on plant health, and deaths of some species.

Predicting the likelihood and extent of impacts to aquatic, riverine and groundwater dependent vegetation resulting from mining operations and related infrastructure facilities can be challenging. For example, it is often not clear to what extent some vegetation species and communities are dependent on groundwater, and therefore, what impacts might result from particular groundwater changes. Changes in groundwater can themselves prove challenging to predict over a range of time and space scales. In some instances, this requires detailed water balance studies. Changes to riparian vegetation frequently occur due to natural variation in stream flow patterns, and wetting and drying cycles of lakes. So distinguishing what changes are due to the direct or indirect impacts of mining operations can be very difficult.

It is important that mines consider the potential hydrological or water quality changes from their operation that impact on aquatic, riparian or phreatophytic vegetation, early in the planning stages of a mining operation. Monitoring and research programs need to be designed and implemented so that the extent and details of any impacts can be revealed and understood. Management programs should be developed to control any impacts, based on the findings of the monitoring and research.

4.6 Introduced organisms and species

Australia has a large number of introduced organisms. During the last 200 years, non-endemic species have established at an alarming rate. About 15 percent of Australian flora—24 mammal, 26 bird, 21 freshwater fish, six reptile, one amphibian, and over 200 known invertebrate species - are now present in wild populations throughout Australia. Therefore, the issue of the prevention of future establishment is important to mining companies at a site and regional level (Low 1999; Allen et al. 2001). In addition, little is known about many non-vascular plant and fungal species.

Mining operations often face a range of problems associated with non-endemic, introduced plant or animal species. Many introduced plant and animal species (for example buffel grass, ruby dock, lantana, parthenium weed, goat, rabbit, pig, fox, cat, cane toad, carp and tilapia) can impact on fragmented habitat and rehabilitated areas associated with mining. Less obvious feral species such as the house mouse, black rat, European carp and European bee are also of concern, however their impacts on biodiversity values are often less understood, or not as obvious. Introduced species can have a significant impact on an area's biodiversity values, and significantly retard development of the post-mining rehabilitated ecosystem.

Introduced species can impact on biodiversity in number of ways, for example:

- some introduced plant species can rapidly establish in cleared or modified environments
- introduced species can inadvertently be transported between mining sites by employees and machinery
- some plant diseases rapidly invade disturbed or modified environments such as those resulting from mining operations
- goats and rabbits grazing on unmined and rehabilitated areas can significantly affect vegetation establishment, reduce diversity and cover, and facilitate erosion which can result in impacts on water quality and aquatic communities
- pigs can disturb vegetation near watercourses and spread soil-borne plant diseases such as *Phytophthora cinnamomi*
- predators such as the fox and cat significantly impact on vertebrate communities in both unmined and rehabilitated areas

- house mice can build up large numbers in rehabilitated areas, impacting on establishment and causing displacement of native species
- in disturbed stream sections, feral fish can establish populations that then impede recovery of native fish populations after rehabilitation.

Native species can also behave like introduced species and alter biodiversity values of an area by increasing in numbers or dominance in the modified environments.

Mining companies need to ensure that their monitoring programs can effectively assess the presence and abundance of any introduced and feral species likely to have detrimental impacts on the biodiversity of surrounding unmined areas, and the re-establishment of biodiversity in rehabilitation.

Management plans should be developed prior to the start of any operations that could contribute to an increase in introduced species or diseases. Relevant state government agriculture or conservation departments are a good source of information about the control of introduced species. Control programs can be complex and may require the cooperation of neighbouring land-holders to be effective. This is especially the case for plant diseases, aggressive environmental weeds and large vertebrate feral species. Useful information on the impacts of terrestrial feral predators on native wildlife, and control methods, is provided in Brennan et al. (2004).

Control methods vary and can include:

- the use of education programs
- hygiene control measures
- control of infestations
- baits or shooting for feral predators
- the exclusion of grazing by the use of fences and tree guards.

4.6.1 Phytosanitation and biosecurity

Biosecurity relates to the protection of the biological integrity of an area through exclusion of introduced pests, weeds and diseases. Phytosanitation, an important component of biosecurity, relates to the treatment of equipment and materials to assist in the prevention of transporting pests and pathogens. A practical example of phytosanitation is the use of wash-down facilities and treatment of the resulting waste-water to reduce disease risk. Spread of weeds such as *Parthenium hysterophorus* and plant pathogens such as *Phytophthora spp.* are commonly controlled in this manner.

For control of other diseases and weeds, construction materials and equipment should be thoroughly inspected, disassembled if necessary, and cleaned prior to arrival on and departure from the site. Attention should be given to imported machinery, or machinery that has come from at-risk areas. The high cost of control methods is justified when measured against the cost of their impacts on economic, social and environmental (including biodiversity) values.

4.7 Rehabilitation

General rehabilitation methods are described in the Leading Practice *Handbook on Mine Rehabilitation* in this series. These describe in detail, material handling procedures, earthworks, topsoil management, vegetation and fauna establishment techniques, and post-establishment maintenance. The reader is encouraged to consult these for the fundamental details of how leading practice rehabilitation should be carried out. To avoid duplication, this sub-section only addresses those issues related to biodiversity re-establishment.

4.7.1 Topsoil handling

Recommended topsoil handling methods are given in the Leading Practice *Handbook on Mine Rehabilitation*. Where topsoil is likely to contain a diversity of native seed representative of the vegetation community that existed prior to mining, there are several important reasons why this seed should be conserved, including:

- conservation of seed in the topsoil can significantly reduce vegetation establishment costs and improve conservation outcomes by ensuring that the relative abundance of species in the seed bank is more likely to reflect that in the vegetation community than might be obtained by designing a seed mix
- the soil seed bank is likely to include species for which seed is expensive, or not able to be collected or purchased
- the seed in topsoil will reflect local genetic provenances, whereas that purchased or collected may not
- some of the triggers for germination may take place in topsoil, whereas seed collected and re-spread may have low germination rates, or require specific treatment.

It is essential that management procedures are implemented where necessary, to ensure that plant pathogens and weeds species, which can have a large impact on plant species diversity, are not spread during soil movement.

4.7.2 Seeding

Seeding is the most common method used around the world for rehabilitation of disturbed or degraded ecosystems. Research and/or site-specific and species specific evaluation are often necessary to ensure maximum benefits from using local seed. The prudent collection, storage and delivery to site of native seed is imperative for all mine rehabilitation programs to maintain seed viability, achieve acceptable species germination rates, establish the required species diversity and reduce seed costs.

Leading practice requires that each stage in the process be incorporated into rehabilitation programs. Failure to effectively follow this process may result in costly loss of species and plant abundance during the rehabilitation process, and in many cases, a failure to understand the reasons for the poor results. As with all ecological rehabilitation programs, good planning from the beginning significantly increases the chances of achieving financially sound and ecologically sustainable outcomes.

Sourcing seed

Seed can be purchased from commercial suppliers or collected on-site. Planning for seed collection should start 12 to 24 months prior to the rehabilitation event to allow for identification of seed collection sources, and adequate collection and processing time. Seasonal variations in seed abundance may require seed to be collected over several seasons to enable collection of sufficient amounts. In the event of a series of good seasons, excess seed can be collected and stored in advance of use (see seed storage and banking).

Wherever possible, local seed should be collected so the rehabilitation program maintains locally adapted forms (genotypes), and continuity and integrity with local genotypes. The use of non-local seed can lead to significant and deleterious impacts upon populations of some native species.

CASE STUDY: Estimating genetic provenance for spinifex (*Triodia* species)

Rio Tinto were required to use only local genetic seed types (local provenance) for rehabilitation of spinifex species at its Argyle Diamond Mines in the Kimberley region of Western Australia. The Argyle mine envelope contained insufficient spinifex abundance to supply seed for rehabilitation programs. It was therefore necessary to conduct research to evaluate the geographical range over which spinifex could be collected without impacting upon measured genetic diversity. A molecular investigation of genetic diversity found that the range of the genetic provenance was far greater than originally expected, extending to 60 km beyond the mine boundary. Such an extensive provenance catchment is unusual for Australian species and is most likely linked to the dispersal characteristic and wind-pollination attributes of spinifex.

Cleaning and sorting to optimise viable seed

Once a seed batch has been sourced, the number of germinable units per unit weight of supplied seed should be determined. Some indication of the number of seedlings expected from a seed batch (either for broadcasting or nursery production) helps to calculate the expected density. Testing seed involves understanding the purity, viability and germinability of a seed batch. Measurement of these three key parameters is explained in Dixon (2006).

Seed storage and banking

Seed banking provides a useful means to build seed lots well ahead of rehabilitation and to capitalise on good seasons when seed is in abundance. It also reduces the annual demands on bushland sources of seed. Most seed can be stored for many years without a loss in viability by adjusting the conditions under which seeds dry to a relative humidity of 20 percent, followed by sealing of seeds in airtight containers. If seed requires a period of time for after-ripening, this must be applied either prior to or immediately after storage retrieval. Care must be taken to ensure that seed storage protocols recommended by supply companies and organisations with expertise in this field are followed. Poor and inadequate storage can result in loss of viability, abnormal seedling growth, delayed germination or reduced growth rates and reduced tolerance to environmental stresses.

Release of seed dormancy

Viable seeds that fail to germinate may have in-built dormancy mechanisms. These seeds require an action to trigger successful germination. The presence of a dormancy mechanism can be detected through a simple germination test based on seed that has been after-ripened for at least three months following collection from the plant. If seed fails to germinate or germination is low, techniques to overcome dormancy may be required (see the case study on smoke treatment). Collected seed from some Australian species can be expensive and have in-built dormancy mechanisms. For many Australian species where initial testing shows deep dormancy issues, a process can be used for determining and resolving dormancy and germinability characteristics. Further detail is provided in Dixon (2006).

CASE STUDY: Using the smoke techniques for rehabilitation of native Australian species

A 48-fold increase in seedling abundance and a 4-fold increase in species present have been achieved following smoke treatment of forest sites where Alcoa World Alumina Australia operates its bauxite mines in the biodiverse south-west of Western Australia. Broad acre application of smoke to topsoil and as a seed treatment for broadcast seed has seen outstanding improvements in seedling and species yields.

Total germinants increased by 85 percent over non-smoke treated seeds with 56 percent more seedlings from topsoil treated with smoke than non-smoked sites. For nursery production, the addition of smoke to seeds or to seed trays sown with seed can elicit high levels of germination in nearly 400 Australian species. Previously it had been difficult or impossible to germinate these seeds. For broadcast seeding, addition of aerosol (dry smoke) or soaking of seeds in 10 percent dilute smoke water for up to 24 hours can double the germination of broadcast seed compared to untreated controls.



Above: Smoke being applied in aerosol form to audit seed bank diversity and quantity from stockpiled topsoil, K. Dixon

In 2004 a Western Australian research group isolated and identified a compound from smoke (a butenolide) that enhances seed germination to the same level observed for plant-derived smoke. The butenolide induces germination in a comprehensive and indicative selection of species known to be smoke-responsive including native species from California, South Africa, Australia and a range of horticultural and crop species. Research is now focused on deriving chemical analogues for more effective rehabilitation opportunities as well as investigating the mode of action of the molecule in native and agricultural species. This discovery represents a highly significant advance in rehabilitation sciences, with significant practical implications.

Effective delivery of seed to site

Delivery of seed-to-site often poses significant technical and logistical problems. Seed loss through wind and water erosion, and seed predation can lead to low establishment rates. Incorrect treatment of seed may lead to large numbers of seeds failing to germinate. Ensuring the seed is at the optimum depth for emergence represents one of the most complex issues—too shallow and the seed may fail to adequately imbibe water or germination may be suppressed by light. Seed that is buried deeper than the one to two cm maximum depth for emergence can render the seedling unable to emerge. Further research is required to ensure the seed remains viable, is buried at the correct depth and remains at the point of delivery while awaiting the germination season. For many native Australian plant seeds, broadcasting untreated seed over an unprepared site is likely to result in poor returns. Rehabilitation practitioners undertaking broadcast seeding should undertake trials to determine the most effective means of seeding.

There are a variety of direct seeding methods using different equipment – air-seeding, hand or machine broadcasting or even helicopter based seeding. All direct seeding methods require the soil to be pre-tilled to create micro-niches for seed lodgement. Recent improvements in direct seeding technology include a one-pass system. This uses a single tine furrow. The seed passes through a spray curtain, which may contain smoke water or other germination promotion agents, as it is dropped into the furrow.

Other developments designed to improve direct seeding include priming (osmo-priming) and cueing of seed, incorporation of germination stimulators, and even anti-stress compounds into or onto the seed or fruit coat. Research is underway to optimise cueing and priming methods for application in direct delivery of native Australian seed to site.

While a lot of information is currently available on seeding, there is still much to be learned. Rehabilitation practitioners who achieve the best outcomes establishing botanical diversity from seeding, are those that are committed to the practice of ‘adaptive management,’ essentially learning as they go to achieve continuous improvement.

4.7.3 Planting seedlings

A detailed summary of issues relating to establishment of vegetation by planting is given in the Leading Practice *Handbook on Mine Rehabilitation*. In some cases planting may not be specifically aimed at increasing biodiversity, but can help provide the soil nutrient, litter and shelter conditions necessary for the establishment of other plant and animal species.

Rehabilitation is often a two-stage operation designed to mimic a natural successional process, with pioneer species planted first, followed by shade tolerant species several years later (for example, in tropical rain forest areas). While more labour intensive than broadcast seeding, this approach can target particular species which are unlikely to recolonise from existing seed sources.

Mining companies that produce their own seedlings can contribute to regional biodiversity initiatives by donating plants to worthy local conservation projects. This may also provide an opportunity to involve the local community in seed collection and propagation of particular species.

4.7.4 Establishing recalcitrant species

Recalcitrant species are those that are difficult to establish using standard horticultural techniques. Without effective seed treatment, it is unlikely that successful germination outcomes will be achieved. The alternative is to use large quantities of seed to compensate for the low percentage germination, which may have significant ecological consequences on wild populations if seed is wild-collected.

Biotechnological solutions are sometimes required for rehabilitation of species where seed, cutting or division methods are low yielding. The most common method employed uses tissue culture to produce many dozens or even hundreds of cloned shoots. These shoots can be

induced to produce roots and then transferred to soil and hardened-off in the greenhouse before planting into rehabilitation programs. A new process with the potential to generate large numbers of plants for rehabilitation using a process of synthetic embryo production is 'somatic embryogenesis'. The process is capable of producing up to 60 000 plantlets from just a gram of starting tissue, usually based on an extracted embryo taken from a seed. Alcoa World Alumina Australia uses a variety of biotechnological methods to generate plants for rehabilitation in one of the world's largest private tissue culture laboratories dedicated to tissue culture.

4.7.5 Establishing rare species

For rare species in rehabilitation programs, special attention needs to be given to matching density, number of plants and genetic diversity of the disturbed populations. If species are listed as rare, rehabilitation practitioners should consult with their local conservation management agency to ensure compliance with state and federal law prior to disturbing or reinstating a rare species. In most cases rare species will have limited seed. Therefore reinstatement or recovery of a rare species in a rehabilitation program will require planting of individually propagated plants.

4.7.6 Transplanting and habitat transfer

Although generally expensive and only used in specialised circumstances, habitat transfer is an option for establishing botanical diversity when other methods fail. It involves the collection and transplanting of whole clumps of plants in patches using, for example, a front-end loader. This can prove useful on a small scale where establishment of particular 'recalcitrant' species, or combinations of species, is a high priority. For example, Consolidated Rutile Limited transplants Grasstrees (*Xanthorrhoea johnsonii*) from in front of its heavy mineral sand mining operations directly into rehabilitated areas (Brennan et al. 2004).

Transplanting can be cost-effective in establishing wetland rushes and sedges. Seed for many of these species can be difficult to obtain, and fluctuating water levels can result in very low success rates from seeding. Transplanting of whole clumps at intervals along the waterline can be a much more reliable way of rapidly establishing some fringing vegetation.

4.7.7 Facilitating natural plant recolonisation

Natural recolonisation refers to processes which lead to native plant species from surrounding areas becoming established in rehabilitation. Over time, wind, water (especially in wetlands), and animals (for example, as seed in bird droppings) can bring many species into a site. Mining companies can monitor data to determine which species recolonise naturally within a reasonable time frame. These species can then be excluded from seed mixes.

Protection and restoration of native vegetation communities adjacent to the mine helps conserve those species likely to contribute to natural recolonisation. However, in many biodiverse temperate ecosystems, particularly shrub dominated systems, seed dispersal

ranges can be short. Some species may require many decades or longer for seed to move more than a few meters from the seed plant. In these ecosystems some caution is required if rehabilitation of a mine site relies upon natural dispersal from surrounding ecosystems.

4.7.8 Re-establishing fauna habitat

Fauna habitat requirements need to be taken into account where the aim of the rehabilitation is to establish a sustainable native ecosystem. Recolonisation of fauna species to rehabilitated areas can be encouraged by the provision of suitable habitat. Establishment of vegetation communities similar to those that existed prior to mining should ensure that suitable habitat will develop over time. Natural fauna recolonisation is preferable to physically reintroducing animals, as fauna will return from adjacent undisturbed areas when the habitat meets their requirements. Physical re-introduction of fauna is expensive and poses a number of risks, and with the exception of fish, is less common.

Some key components of fauna species' habitat requirements may not be present in rehabilitation for many decades. Examples of how some companies have addressed these habitat deficiencies include:

- transplanting of vegetation (grasstrees, macrophytes, significant species)
- conservation and re-use of vegetation as a mulch to provide erosion protection and nutrients, and shelter for small invertebrates, mammals and reptiles
- the construction of artificial tree hollows and nest boxes to provide shelter and breeding habitat for many bird and mammal species
- the return of cleared trees and snags to establish shelter in the form of logs and log piles, which many species shelter in or under
- construction of reptile or aquatic habitat by limited use of boulders and rock piles/groynes
- construction of perches used by raptors and other birds (who may introduce seeds and control pests)
- establishment of old dead trees ('stags') which provide hollows, crevices, exfoliating bark and the like, all of which provide useful shelter for many smaller reptile and invertebrate species.

An Australian Centre for Minerals Extension and Research project 'Innovative Techniques for Establishing Fauna Habitat Following Mining' provides practical advice on methods mining companies are using to establish these and other fauna habitats (see www.acmer.uq.edu.au).

4.7.9 Revegetation of non-mined areas

As noted in Section 3, rehabilitation objectives pertaining to biodiversity should not be limited to the mine footprint and immediately adjacent areas. Mining companies committed to leading practice biodiversity management are developing opportunities for biodiversity enhancement on a whole-of-lease basis. These companies take into account the views of the community and other stakeholders, as well as regional land-use plans, catchment management plans, Landcare programs, and other initiatives.

As well as the standard revegetation techniques, rehabilitation of degraded areas might need to include other measures such as reducing grazing, controlling introduced predators and herbivores, fire management, weed eradication, establishment of nest boxes and other techniques. These measures may be needed to protect water quality, enhance conservation values, and provide sources of plant and animal recruitment to rehabilitated areas over the longer term. Where areas have been severely degraded, losing plant propagules and/or topsoil, re-establishment of diverse vegetation associations can prove difficult. In such cases, local conservation and Landcare groups can provide expertise on cost-effective techniques and initiatives.

4.8 Research for improvement

Because all mines and the environments in which they operate are unique, well-designed research projects are an integral component of all leading practice biodiversity management programs. Procedures used to minimise impacts on biodiversity values, and re-establish them following the impacts often need some fine-tuning for each site to maximise their effectiveness.

Research programs often focus on understanding the following aspects of ecosystem processes:

- links to soil
- water and hydrological characteristics
- development of cost-effective monitoring methods
- successional changes
- the re-establishment of biodiversity values following disturbance.

Research trials are often needed to fine-tune rehabilitation techniques that have worked well at other mines. They may also be needed to develop methods of rehabilitating difficult sites. Problems identified through monitoring programs may require research projects to maintain high standards of biodiversity management, and contribute to continuous improvement—a key component of the EMS.

Opportunities will often exist for integration of research across sectors. The costs and expertise of the mining industry research can, in some cases, be shared with other sectors such as forestry, agriculture, water resources, and other industries that have pollution control programs.

Opportunities should also be sought for integrating the research programs of mining companies with those of government, academic research institutions and specialist scientists. For example, research pertaining to rehabilitation operations will usually require the involvement of technical experts from research institutions such as universities, botanic gardens, museums, zoos, consultants and CSIRO. Links between the various company research and monitoring programs will also often be required. As well as revegetation these might include soil development, nutrient cycling, fauna monitoring, timber and agricultural production.



5.0 MONITORING PERFORMANCE

KEY MESSAGES

- Cost-effective research and monitoring programs are essential for achieving continuous improvement and determining whether rehabilitation objectives have been met.
- The objectives of monitoring must be clearly understood, and monitoring programs carefully designed to answer the questions being asked.
- Depending on the information sought and available resources and expertise, biodiversity monitoring may be carried out by company staff, consultants, community (including indigenous) groups, school groups, research institutions, or as student projects.
- The scale of monitoring, and the indicators monitored, need to be carefully considered.
- Monitoring of vegetation and floristics is important for achieving good rehabilitation, while monitoring of vertebrate fauna is important to understand and facilitate their conservation and recolonisation. Although invertebrates constitute at least 95 percent of terrestrial fauna species, few mining companies monitor impacts on invertebrates and recolonisation processes of rehabilitation.
- Benthic macroinvertebrates are increasingly used for aquatic ecosystem biodiversity and health monitoring, particularly in freshwater ecosystems. However, monitoring of ephemeral streams and lakes pose different challenges and in many cases methods are still being developed.
- Completion criteria need to take into account both biodiversity, and ecological processes and functions, and should represent the minimum standards the mine is expected to meet. A number of mines now also adopt higher, non-binding internal standards as part of their continuous improvement process.

Monitoring is used by mining companies and stakeholders to assess the effectiveness of biodiversity management measures, and develop improved biodiversity conservation and rehabilitation practices.

Good monitoring programs determine the impacts of mining and exploration activities, and assess the effectiveness of the resulting management and rehabilitation programs. When combined with research and field trials, monitoring can help determine which management techniques are effective in conserving and restoring biodiversity, and which are not. This is central to the principle of continuous improvement.

As well as measuring the well-being and recovery of species, communities and ecosystems, monitoring is needed to document management actions such as water management techniques and rehabilitation practices. The causes of any problems detected in subsequent monitoring can then be determined, and adaptive management procedures developed and implemented.

Monitoring can include a range of repeated measures and sampling of indicators over space and time, to assess changes and compare these with natural variability. It may be carried out in-house, by external consultants, or in conjunction with academic institutions or conservation groups. Whichever approach is used, it is important that the procedures are transparent, and high standards of quality control are maintained.

Prior to embarking on a monitoring program it is critical to review previous literature and data that may be relevant in a local and regional context. This is particularly relevant for areas where leases have changed hands between exploration and mining companies.

Leading practice mining companies are now taking a more holistic approach, rather than a site specific approach. Being proactive rather than reactive to needs reduces the risk of not considering biodiversity values adequately, which can lead to delays in the approvals process and increase liabilities.

This Section describes in detail the reasons for monitoring biodiversity, who should be involved, the techniques used for monitoring, the development of biodiversity completion criteria as part of the overall mine closure plan, and reporting.

5.1 Why monitor?

Monitoring is an essential component of leading practice biodiversity management for any mining operation. Cost-effective biodiversity monitoring programs should fulfil a number of purposes, specifically:

- fulfill all regulatory requirements and other commitments developed during the EIA process and be included in subsequent environmental management plans
- act as a quality control checklist to confirm that environmental management actions are carried out according to agreed procedures
- provide the temporal and successional data necessary for a company to assess and manage impacts on biodiversity, and thereby achieve continuous improvement. This will include both monitoring data on environmental performance ('how is it going?'), and related research data comparing methods of biodiversity management ('how can we improve it?')
- assess the effectiveness of procedures designed to minimise impacts on biodiversity, and maximise the re-establishment of biodiversity values following the cessation of operations (for example for minerals processing facilities) and rehabilitation/recovery of degraded areas (mined, disturbed or unmined)

- identify the need for research into specific problems (as noted in Section 4), and provide relevant data
- facilitate transparency and a co-operative approach to biodiversity management by providing information for stakeholders and public relations purposes
- reveal to the company and key stakeholders whether biodiversity objectives, and associated completion criteria and standards are being, or will be, met within an acceptable time frame, as part of the overall mine closure process
- jointly with key research projects, enable the company and stakeholders to assess long-term sustainability of rehabilitated areas under the proposed post-mining management regime.

Monitoring programs that assess impacts on, and recovery of biodiversity, should be designed in a manner that ensures they will fulfil the above purposes, as well as taking into account the practicalities of monitoring, cost and safety. Recommended procedures for designing such monitoring programs are presented in Section 5.3.

5.2 Who to involve?

Monitoring can be undertaken by a range of different groups. Depending on the data being collected there are opportunities for involving school groups, community groups, indigenous groups, consultants, researchers, other specialists and operational staff.

The involvement of local school groups in some monitoring programs (for example, Frog Watch or Water Watch programs in wetlands and streams) can increase students' appreciation of the mining industry's role in studying biodiversity values, and possibly attract them into the industry or related fields.

The involvement of community groups (for example, Bushcare, Landcare, Coastcare and catchment groups) is a mechanism of maintaining good neighbourhood relationships, as well as gaining regional datasets to place specific local data into context.

The involvement of indigenous groups can assist in the exchange of local and historical knowledge, and have a direct input into operational activities.

Consultants, researchers and specialists tend to supply specialist skills that cannot be drawn from other sectors. These groups have developed extensive professional networks that can assist in adaptive management of direct and indirect impacts of mining and exploration activities on biodiversity values.

Graduate programs can provide an effective mechanism for targeted research on species, ecosystems, key threatening processes and particular aspects of biodiversity interactions. This may be a key opportunity for fostering the interests of potential research scientists which will underpin the well-being of the mining industry in the future.

There is also a key role for independent peer reviews, either through the editorial process of journals or through review by experienced researchers.

Operational staff must always be involved as they are a source of site data and information on operational matters. They also play a key role in adaptive management through incorporating research findings back into the operation.

Personnel conducting the monitoring must have the necessary skills, equipment and permits, including ethics approval. Obtaining permits can be a lengthy process, for example, fishing permits in Queensland are site specific, require native title notification and take more than six weeks to obtain.

5.3 What to monitor?

Monitoring biodiversity is complex, the levels of biodiversity (genetic, species and ecosystem) and the large variety within each makes it impossible to monitor all aspects of biodiversity. Decisions, therefore, need to be made regarding the likely key issues relating to biodiversity management, including key stakeholder concerns. These will vary considerably between mining projects, depending on such factors as the location, scale, timing and duration of operations, and of course, the biodiversity values present.

Two key aspects that requiring consideration relate to scale and indicators.

1. The scale of monitoring is based on the scale of impacts. This will determine whether methods such as broadscale remote sensing or detailed monitoring of plots and quadrats are appropriate.
2. Indicators are parameters that are monitored and used to assess key aspects of ecosystem impacts and recovery. Monitoring a carefully selected set of indicators will provide the mining company and other stakeholders with the information required to assess impacts, rehabilitation performance and sustainability.

Monitoring should document the type of species present, where they occur (in relation to landform, soils and vegetation types), how abundant or rare they are, and changes over time. These changes may be due to natural occurrences (for example fire or drought), or human-induced activity, including both mining and non-mining related impacts.

In recent decades, the aim of monitoring has shifted from simply defining biological values in a particular location, to a wider assessment of these values in relation to factors that influence them, and also key ecosystem function processes.

Data should be collected in a manner that assists in the initial definition of values, and also in the understanding of factors that influence these values, helping to optimise their management. As with any monitoring, it is essential that techniques be standardised over time and between sites to enable the effective assessment of impacts, management practices, and rehabilitation.

Secondary impacts are also possible when mines are established in relatively undisturbed areas. These can include changes in grazing practices, wood gathering, hunting, fishing, introduction of pets, road kills of native species, and disturbances resulting from the use of off-road recreation vehicles. The monitoring program should be designed to assess the extent of impacts and the effectiveness of management techniques.

Specific aspects of biodiversity monitoring are discussed in the following sub-sections. References to more detailed information on monitoring design are listed in the references and further reading sections.

5.3.1 Species Level Monitoring

Flora and vegetation

Monitoring techniques for flora and vegetation tend to be specialised, requiring a range of taxonomic, ecological and analytical skills. In Australia, the diversity of flora is a challenge for researchers. Also, there is a declining interest in taxonomy as a career path for young scientists.

Data collected should include:

- presence/absence data of taxon
- abundance parameters (density, percentage foliage cover, and/or frequency)
- dominance
- information on life forms and regeneration strategies
- spatial extent of species
- habitat and site preferences of species and ecosystems
- rate of establishment
- growth rates
- population and community structures
- life expectancy of different taxa
- responses of species to a range of influences (for example fire and hydrological shifts).

Monitoring data should also investigate the patterns between species and different threatening processes, and shifts in species and ecosystems in relation to site parameters and conditions. For example, a particular mining operation may alter the growth medium resulting in a consequential shift in species that can establish and persist in the modified environment.

Implementing leading practice vegetation and floristic monitoring requires a robust taxonomic knowledge of all plant groups likely to be impacted by mining. This knowledge may have significant bearing upon the right to mine an area. Recently, surveys conducted at some mines using more detailed taxonomic investigation have found that species previously thought to be common are new to science, and rare. This has implications concerning potential impacts on expansion of mining activities.

A recent challenge faced by the mining industry is the decline of taxonomy as a preferred career path, highlighted in a range of policy and review documents including National State of the Environment Reports in 2001 and 2006. To avoid monitoring standards declining due to the data collected being highly variable and unreliable, the mining industry can assist by fostering and encouraging younger graduates in this research area.

Vertebrate fauna

Monitoring techniques for vertebrate fauna are specialised, often labour intensive, and vary according to the group being studied. Typical techniques include:

- the use of ANABAT bat detectors
- identification of frog calls
- mammal and reptile trapping
- bird sightings and call identification
- fish sampling using observation
- nets
- angling and electro-fishing
- observation of tree hollows and stags
- use of mammal hair tubes
- 'camera trapping' (where the animal triggers a photo of itself)
- identification of tracks and scats.

Selecting which species or aspects of the vertebrate community to monitor is critical. Vertebrate monitoring programs generally focus on species presence/absence and their abundance. Particular attention should be given to officially listed rare species, or those considered vulnerable, of concern, habitat dependant, or known to be declining (for example *EPBC Act*-listed species). More abundant species or groups that serve particular ecological roles, such as honeyeaters (pollination) and grazing or algivorous species, should also be monitored. For some species, monitoring programs should be designed in relation to threatening processes and recovery plans. It is also essential that any impacts due to the mining operation be taken into account in relation to cumulative impacts due to habitat clearing, fox and/or cat predation, feral species abundance, background water quality, dieback related vegetation changes, and the like.

Compared to flora, the mobility of vertebrates, necessitates a broadscale approach to monitoring. As well as focussing on direct impacts and nearby areas, monitoring may be required to assess the effectiveness of impact management and rehabilitation on a whole-of-lease scale, and the effectiveness of biodiversity offsets. Examples of these might include fox baiting, the establishment of corridors, development of partnerships with local conservation organisations, and the removal or control of grazing to promote vegetation recovery, and therefore recovery of bird and small mammal populations.

When designing vertebrate fauna monitoring programs, it is important to recognise the considerable variation between species. Species can vary in terms of the extent to which they are impacted, and the rate they recover following cessation of the impact and/or rehabilitation. It is therefore often inappropriate to monitor only one or two species and assume that the findings will apply to all species. Recognising that not all species can be monitored in detail, great care must be taken to ensure that those that are monitored represent the most important in terms of their status, and are the best indicators of mining-related impacts and post-mining recovery.

Where possible, fauna monitoring programs should be co-ordinated with flora monitoring programs to help identify the causes of any changes recorded. Some vertebrate groups such as small mammals and reptiles can serve as useful indicators of the extent to which particular components of species' habitat, such as shelter, have been replaced. Links between floristic diversity and the diversity or abundance of honeyeaters and/or insectivorous birds can also prove useful in assessing the extent and causes of impacts on ecosystems, as well as recovery. For fish, monitoring of water quality and hydrological parameters are obviously critical for interpreting the causes of any changes observed. In all instances, the design of the monitoring program is the key to assessing the extent and causes of impacts on vertebrate fauna species and populations.

Numbers of vertebrate species present are usually small compared with invertebrates. In many cases, this will preclude the use of normal parametric statistical analysis techniques. However, for some fauna groups such as birds and fish, analyses may be possible. For example, multivariate analysis techniques such as the use of diversity and similarity indices, and classification and ordination of community composition, can prove useful when comparing such assemblages to assess impacts and/or recovery.

Vertebrate fauna monitoring should also include feral species as these can have a significant impact on native flora and fauna. Knowing the extent of fox and cat predation, and managing this, can prove very important in assessing mining related impacts and promoting post-mining recovery of a range of vertebrate species. Other feral species such as carp, tilapia, goats and pigs can have a significant impact on vegetation and other habitat structures, with secondary impacts on vertebrate fauna. It is important that the effectiveness of all feral fauna control programs be assessed.

Terrestrial invertebrate fauna

Invertebrates such as insects, centipedes, spiders, earthworms and snails, constitute at least 95 percent of the animal species that exist on land. In any given area, invertebrates far outweigh birds and terrestrial vertebrates in terms of biomass. It is therefore not surprising that invertebrates play a pivotal role in the functioning of ecosystems, both natural and disturbed (for example facilitating soil aeration and drainage, litter decomposition and nutrient cycling, pollination, seed dispersal and herbivory, as well as providing a source of food for vertebrate predators). It follows that the colonisation of an abundant and diverse fauna within a particular taxonomic group should indicate the effective operation of associated ecosystem processes.

Mining companies are increasingly considering invertebrates in their monitoring of ecosystem recovery after rehabilitation, or of impacts such as the creation of edge-effects, spread of forest diseases like *Phytophthora*, or of pollution. Several taxa are now being used as bioindicators of various facets of the environment, including:

- ants (general indicators of the nature of the habitat and of invertebrate prey)
- spiders (good indicators of habitat structure)
- hemipteran sucking bugs (indicators of plant composition and health)
- termites (indicators of decomposition and soil structuring)
- springtails (indicators of decomposition and nutrient cycling).

Monitoring invertebrate fauna poses specific challenges for those wishing to implement leading practice programs. However, none are insurmountable.

The first challenge relates to the sheer diversity of the invertebrate fauna; no mining company could be expected to survey and identify all of the species that occur within their lease. One approach is to focus on a specified range of taxa which represent a complementary set of ecosystem processes. Candidates include: termites–soil structure; springtails–decomposition; sucking bugs–herbivory; and flies, beetles or ants as indicators of several processes. Another approach is to consider one taxonomic group on the grounds, that its diversity may act as a surrogate for the diversity of other, unsurveyed, groups. Recent studies in Western Australian sand and bauxite mines have indicated that ants consistently reflect the diversity and community composition of many other invertebrate groups. For this reason, ants are widely used in Australia as indicators of rehabilitation success or of mine-associated threats to ecosystems.

The second challenge is the wide range of techniques required to sample terrestrial invertebrates. Most of are specific to certain strata of the habitat or to particular groups of animals. Casual collecting should be avoided. Instead, a standardised sampling protocol is strongly recommended so that a good range of taxa from each stratum are sampled, enabling data to be compared across the mining lease and between different surveys. Various protocols have been suggested, involving Winkler sacks for litter fauna, pitfall traps for ground-active fauna, vacuum samples for the shrub-associated fauna, and beating for groups that live on trees.

The third challenge is the high degree of seasonality of the invertebrate fauna. A survey at one time of the year may reveal different species to those sampled at another. As seasons differ in different regions of Australia and throughout the world, creating a universal prescription on the best time to sample is impossible. However, the warm, moist conditions of spring tend to yield the highest return in number of species. Depending on funds, it is recommended that surveys be performed in the middle of each of the four seasons. If funding is limited, then sampling once in spring and once six months later is recommended.

A final challenge is the possible existence of rare or threatened invertebrates. The number of officially listed invertebrate species is far less than the number of plant or vertebrate species. This is simply a reflection of insufficient knowledge about the status of most invertebrates, and

whether they are rare or threatened. Nevertheless, listed species could occur in the mining lease, and their status is just as important as that of plants or vertebrates. Leading practice biodiversity management necessitates that they receive the same degree of consideration.

Recent cost-benefit analyses of plant, vertebrate and invertebrate surveys show that invertebrate data are cost-effective to gather and potentially high in information content. Being the most diverse members of the animal kingdom, their inclusion in surveys can contribute to data on physical factors and plant and vertebrate communities in habitats. As well as strengthening the conclusions reached from a study of these aspects alone, invertebrate data can provide an indication of the degree of re-establishment of ecosystem functioning.

CASE STUDY: The use of invertebrates as indicators to monitor development of mine rehabilitation

Invertebrates comprise the bulk of animal biomass and most of its biodiversity. They serve a vital role in key ecological processes such as pedogenesis, nutrient cycling, and pollination. Many invertebrate groups can be relatively easily sampled. The large numbers and diversity collected permit the use of quantitative statistical procedures, which enables detailed comparison of rehabilitated sites over time, or between mined and unmined sites.

A recent study by Curtin University (Majer, JD, Orabi, G & Bisevac, L 2006) of two Western Australian mines evaluated the cost-effectiveness of using a range of invertebrate groups for monitoring rehabilitation, and in the development of rehabilitation. Plants, invertebrates and vertebrates were sampled in ten rehabilitated areas and in four unmined heath controls at Iluka's mineral sand mine at Eneabba and the Worsley Alumina bauxite mine at Boddington. The type of information obtained, and the time taken to sample, sort and data process each group, was measured for comparison. Some leading practice companies are now in the process of incorporating invertebrates in their sampling.

Although plants were the most diverse group, beetles, spiders and ants were comparable. Birds were reasonably diverse, but reptiles, amphibians and mammals were represented by few species.

The results of the study indicate that collection of invertebrates can be undertaken almost as rapidly as for plant data, and much more rapidly than for vertebrates. Whilst some invertebrate groups require specialised sampling procedures and taxonomic expertise, the time to process invertebrate material was found to be in the same order as for plants. The cumulative time taken to obtain and process invertebrate material was generally less than for vertebrates. The information yield for invertebrates, in terms of number of species per plot, was almost as high as for plants, and considerably higher than

for amphibians, reptiles and mammals. Given that plants are known to be poor indicators of invertebrate biodiversity, vegetation and floristic monitoring alone would not give a true picture of the extent of biodiversity recovery.



Above: Cerapachys Princes: Predatory ant favoured in restored sites, A.Gove

Western Australia, a uranium mine in the Northern Territory (*Ranger*), and a coal mine (*Callide*) in Queensland.

Being the most diverse members of the animal kingdom, the inclusion of invertebrates in surveys can contribute to the data on physical factors and plant and vertebrate communities in restored areas. Invertebrate data can also provide an indication of the degree of re-establishment of ecosystem functioning.

Overall, the invertebrate data proved to be cost-effective to gather and potentially high in information content. In studies at the two mines and elsewhere, groups such as ants, beetles, spiders, sucking bugs, mites and termites have produced valuable data on the way in which the ecosystem is recovering. Ants, for example, are now used to measure ecosystem recovery at bauxite (*Alcoa*) and mineral sand (*Iluka*) mines in

Despite the efficiency in yielding data, inclusion of invertebrates in completion criteria does represent a measurable time and cost commitment. In cases where a company has several areas of rehabilitation to assess, it is recommended that surveys be performed in a representative sub-set of these areas, and that the results be applied to the remaining unsurveyed areas.

Aquatic invertebrate fauna

Benthic macroinvertebrates (such as snails, clams, and aquatic worms) have been adopted worldwide as a standard indicator group for aquatic ecosystem biodiversity and health monitoring, particularly in freshwater ecosystems. They are being increasingly used in estuarine and marine ecosystems. This stems largely from their ease of sampling with well-established, standardised sampling methods. At least some life stages are relatively sedentary, and therefore reflective of local conditions, and they are taxonomically and trophically diverse. ANZECC/ARMCANZ (2000) provides further discussion of the utility and potential difficulties associated with the use of these groups for monitoring and assessing water-quality related biodiversity (see Section 8.1.2 as a starting point). A selection of standardised methods is also

provided in the guidelines (Appendix 3 to Volume 2). Note that these methods do not represent a comprehensive list of methods, but reflect those that were regarded as well standardised and in common use at the time of compilation of the guideline documents.

A recent review of water quality monitoring methods for temporary waters (Smith et al. 2004) identified a number of potential shortcomings in temporary waters for some of the ANZECC/ARMCANZ (2000) standard methods of monitoring macroinvertebrates, and likely limitations to the sensitivity of those methods for such ecosystems. The review nominated several other invertebrate monitoring approaches that warranted further investigation, including the use of hyporheos (organisms inhabiting subsurface waters in the stream bed) and microcrustacea. The latter were of particular potential utility, because they were ubiquitous, rapid colonisers of temporary waters, and the group was widely used for toxicity testing (unlike macroinvertebrates), enabling inter-relating field monitoring and toxicity database derived sensitivity data. These approaches are currently being investigated and/or implemented by leading practice mining companies in semi-arid regions of Australia.

Aquatic invertebrate monitoring is rapidly gaining ground as a standard component of the set of biodiversity monitoring tools used by the mining industry in Australia.

Other biota

Other biota can perform critical roles in ecosystem function and rehabilitation, and therefore are taken into account in leading practice monitoring and research programs. Two such examples are mycorrhizal fungi, and diatoms.

Mycorrhiza (specialised beneficial associations between a fungus and a plant root system) represent widespread, common and significant components of most terrestrial ecosystems. Mycorrhiza function as key agents in the sequestering of nutrients (particularly from substrates such as organics) from complex substrates and improving plant growth and development particularly under adverse conditions. Management of mycorrhizal fungi in topsoils is critical for ensuring that reinstated native ecosystems have the best possible opportunity to recover to full levels of sustainable growth and ecosystem function. Healthy mycorrhizal associations may also be important for minimising disease impacts upon plants.

Diatoms are generally cosmopolitan, taxonomically diverse, and with well established sensitivities to salinity, acidity, nutrients and other water quality parameters (at least for some species) and can be ideal biomonitors for assessment of environmental changes. Therefore, they provide a promising focus for pre-mining and post-mining studies. Diatoms have been used by some leading practice companies in conjunction with invertebrates, for example, in:

- 'pre-discharge dewatering' studies in Western Australian inland salt lakes
- assessment of acid rock drainage impacts in South Australia and the Northern Territory
- for assessment of salt and suspended sediment tolerance of temporary streams in Queensland.

The potential wide-spread utility of diatom approaches is reflected in their adoption as indicators under the National Land and Water Resources Audit National River Health Urban sub-program.

Direct Toxicity Assessment

Direct Toxicity Assessment (DTA) is a proactive, predictive approach to biodiversity monitoring and management that is included as a recommended early detection approach in ANZECC/ARMCANZ (2000). It is also incorporated as the ultimate sediment quality assessment tool in the risk management framework of the National Ocean Disposal Guidelines for Dredged Materials (DEH 2002). Over the last decade species sensitivity distribution methods have been developed to translate laboratory-based toxicity data into predictions of potential biodiversity impacts resulting from the release of contaminants. This has made whole effluent toxicity testing a much more precise and practical method of assessing potential environmental risks. This approach was the preferred basis for developing the default water quality trigger values in ANZECC/ARMCANZ (2000) and was also recommended as a potentially useful tool for pre-release assessment of effluents for temporary waters in the recent ACMER review. Leading practice companies are making use of DTA for both setting site-specific water quality objectives, and for environmental risk assessment before release of mine site effluents.

5.3.2 Ecosystem level monitoring

Ecosystem function and biodiversity

The importance of biodiversity in relation to ecosystem function is noted in Section 2. Natural ecosystems provide a wide range of functions. Ecosystem sustainability type functions include the role of some species in protection from erosion, the interdependency of species, and the role of different species in successional processes such as recovery following natural and man-induced disturbances. Service type functions include protection of water quality, sustainable utilisation (for example timber, beekeeping), traditional foods, medicines and other materials for indigenous groups, cultural values and tourism. How ecosystem function is measured and monitored depends on which functions are identified as important and potentially impacted by the mining operation.

Detailed monitoring programs such as those conducted by Alcoa, Worsley Alumina, Iluka, CRL and Oaky Creek Coal provide detailed information on botanical diversity and successional process over time in both mined and unmined areas, or reference sites. They measure both impacts and recovery, and include the assessment of erosion, and development of biomass and the soil nutrient bank. Life forms, regeneration strategies and site preferences are also taken into account in some monitoring and research programs. Fauna monitoring programs currently under way, or planned for some of these and other mines, provide detailed information on the diversity and abundance of fauna species, as described above. Together, the information from monitoring programs such as these enables managers to answer many of the questions that may be posed in relation to biodiversity and ecosystem function.

Ecosystem Function Analysis (EFA) is a procedure that some mines in different regions of Australia use to assess ecosystem function and recovery following disturbance. The technique was developed by CSIRO as part of an industry and government-funded ACMER project (Tongway 1999; Tongway & Hindley 2003). It is intended to be a rapid assessment technique for measuring the development of ecosystem processes and long-term sustainability. EFA consists of three components, namely Landscape Function Analysis (LFA), which assesses soil development and stability; vegetation dynamics, which monitors development of vegetation; and habitat complexity, which assesses fauna habitat. Development of the ecosystem is measured by using EFA to compare rehabilitated versus analogue (or reference) sites, different aged rehabilitated sites, the same rehabilitated sites over time, and sites rehabilitated using different techniques.

Any rehabilitation designed to establish a sustainable native ecosystem must take biodiversity into account to an extent that depends on the specific mine's objectives. Some mines and regulators are now of the opinion that EFA should only be used as one of a set of assessment tools. Each mine therefore needs to give consideration to what methods will be used to monitor ecosystem function in relation to biodiversity.

The ANZECC/ARMCANZ (2000) Water Quality Guidelines state that direct measures of ecosystem function may be used as an alternative to direct or indirect measures of biodiversity for monitoring of water quality. For example, macroinvertebrate community composition has low temporal and spatial persistence in temporary waters (Smith et al. 2004). That is, there is a high rate of taxonomic turnover between sites and times due to the generally very high migration rate and the large random component to successful colonisation of, and population establishment within, temporary water bodies. Therefore, monitoring using macroinvertebrate biodiversity measures can have little predictive capacity. In contrast, there is evidence that ecosystem function is much more stable, probably due to functional redundancy among the many potential colonists of the isolated water bodies. Therefore, measurement of ecosystem function may be a substantially more robust and sensitive monitor of mining impacts than macroinvertebrate structure.

Ecosystem metabolism is the most commonly applied ecosystem function measure by Australian researchers. Proposed in the 1950s it has only gained acceptance as an ecosystem health monitoring tool in Australia since the late 1990s. However, it has largely been applied to gradients of nutrient and light impacts and of cyanide. Whilst promising, the sensitivity of this approach to contaminants that do not directly affect photosynthesis or respiration pathways, including many of direct relevance to the mining industry, remains unknown. Leading practice can involve considering approaches such as this, however they are not yet considered an accepted standard.

Monitoring impacts and biodiversity recovery

Some form of monitoring will be required at all stages of the mining operation, from the commencement of exploration to beyond mine closure. Initial monitoring is important for obtaining baseline biodiversity data prior to any disturbance, and enabling early incorporation

of environmental risks and liabilities into feasibility assessments. It supplements the information obtained in pre-mining surveys, and should be conducted over a number of years to capture seasonal variation, and variation between years. Monitoring during the operational stages is important for assessing the presence and extent of impacts. Finally, monitoring during the rehabilitation stages through to post-closure can determine the extent of recovery following disturbance, whether rehabilitation objectives have been met, and the extent to which rehabilitation is likely to be sustainable under the proposed post-mining land use.

Any monitoring program needs critical rigour in the design phase so that the direct and indirect impacts of mining can be separated from the variation in other natural factors operating in the systems such as fire, drought, grazing and shifts in seasonal conditions. Monitoring should include a range of datasets to assist in defining the type of impacts, as well as their extent and magnitude. The impacts due to changes in vegetative cover, habitats, hydrology or water quality (for example, sediments, heavy metals, ARD), noise, dust, atmospheric emissions from mineral processing facilities, and deaths on tailings storage facilities (for example, those containing cyanide or caustic liquor) should be included in any program.

Monitoring to assess impacts on, and recovery of, biodiversity are often related, with recovery towards the pre-mining state occurring once impacts have been identified and managed, or rehabilitation commenced. A sound experimental design should be used wherever possible, with an appropriate sampling strategy. Adequate replication will ensure that statistical analysis can be applied to confirm whether a real impact has occurred. The ANZECC/ ARMCANZ (2000) Water Quality Guidelines, emphasise that monitoring programs should focus on protection of the biodiversity in the receiving environment.

5.4 Key performance indicators and completion criteria

As noted in a number of the preceding sub-sections, indicators are needed for the cost-effective monitoring of biodiversity impacts and recovery. For biodiversity, these can include a range of measures such as abundance of particular key species, species richness, diversity, similarity to undisturbed reference sites, and a variety of multivariate classification and ordination techniques. Whichever measures are selected, they must unequivocally indicate whether an impact is occurring, and/or whether any progress is being made toward a particular management goal established as described in Section 3.

The most useful indicators also reveal important information about aspects that are not monitored. For example, research may be needed to demonstrate that measuring the impact of a particular pollutant on one aquatic invertebrate species or group, effectively demonstrates that other groups will (or will not) be affected. This can save the cost of having to monitor all groups. Together, the selected key performance indicators (KPIs) should enable the mine to determine whether those environmental management objectives relating to biodiversity have been met.

Development of completion criteria to confirm the re-establishment of biodiversity is complex due to natural variability over space and time, uncertainties regarding what might be achievable, and difficulties associated with demonstrating sustainability for the particular post-mining land use. Recommended approaches are described in detail in Nichols (2004, 2005 and 2006). In short, these involve:

- setting objectives and draft criteria
- implementing leading practice rehabilitation
- monitoring
- revising the criteria based on good quality monitoring data, in conjunction with stakeholders, and then determining, with regulators, whether the criteria are suitable for adoption as formal completion criteria.

If effectively adopted, this procedure helps ensure that the criteria can be met within an agreed time frame, provided leading practice rehabilitation is carried out, and they will meet the expectations of key stakeholder groups.

As with KPIs, completion criteria need to take into account both biodiversity, and ecological processes and functions. Generally, they should represent the minimum standards the mine is expected to meet. However, a number of mines now also adopt higher, internal standards as part of their continuous improvement process. The latter should not be formal binding commitments, because factors beyond the mine's control (for example, encountering unexpected soil material or changes in climatic conditions, inability to propagate particular plant species) may be encountered.

5.5 Reporting

The effective transfer of information between stakeholders is a critical component of leading practice biodiversity management. Leading practice can involve the development of measurable performance indicators for reporting in collaboration with NGOs and on a project specific basis to local communities and indigenous groups, and the integration of this process into public reporting on biodiversity issues are elements. Good communication helps ensure that mining companies, government, the community and interested NGOs have access to relevant information on biodiversity values, management strategies (including objectives and criteria), and data on the effectiveness of management actions and rehabilitation performance. Reporting may vary from higher level detail, such as that on 2002 global reporting initiative indicators concerned with biodiversity (ICMM 2006), through to data on aquatic fauna monitoring surveys, provided to government and interested stakeholders.

Reporting on biodiversity management may be voluntary or compulsory, such as the requirement in most states for annual environmental reports. An essential first step in the reporting process is to identify users and their information requirements, as described in ANZECC/ARMCANZ (2000). This enables the mining company to tailor the information content and level of technical detail to the intended audience. Given that increasing numbers of mining companies now recognise the business case for leading practice biodiversity management, it is important that they not only meet all requirements for compulsory reporting, but also be proactive in reporting to key stakeholders according to their information requirements. Companies can achieve this by using procedures such as those described in ANZECC/ARMCANZ (2000), and in the *Leading Practice Handbook on Community Engagement and Development*. Community expectations of leading practice reporting include reporting of challenges, derivations from commitments, any negative outcomes in relation to biodiversity, and successes and positive outcomes.



6.0 CONCLUSIONS

In recent years there has been a significant increase in the extent to which the importance of biodiversity values are recognised. Society and the mining industry now recognise that, as well as possessing intrinsic value, biological diversity is important for a range of reasons including social, economic, environmental, cultural, and spiritual. Mining companies that adopt leading practice environmental management procedures now accept the compelling business case for high biodiversity management standards.

Complying with all legislative requirements remains essential, but mining companies that are widely recognised for implementing leading practice frequently go beyond legal imperatives. For example, through surveys and research they provide valuable information on an area's biodiversity values, ecological processes and services, and the effectiveness of management and rehabilitation practices. Rehabilitation of unmined but degraded areas, and the linkage of these to rehabilitated sites and remnant vegetation, can significantly reduce overall impacts and help restore an area's local flora, fauna, and associated values. Much can be achieved through applying general biodiversity management procedures, but each mine and its environment are unique. Companies that achieve the best results are those that adopt a 'learn as you go' approach, and implement sound monitoring and research programs. Liaison with government, the community, including indigenous peoples, researchers, NGOs and others, is critical when developing biodiversity management programs that achieve the best outcomes. Increasingly, mining companies are forming partnerships with NGOs and other organisations to share expertise and resources.

Once mining impacts have been recognised and avoided, minimised, mitigated (for example by rehabilitation) or offset, long-term management solutions need to be put in place to ensure that the resources, funding and expertise necessary for ongoing biodiversity conservation are available.

Not all mining companies currently use leading practice biodiversity management in parts or all of their operations. Areas where there are frequently opportunities for improvement include:

- recognition of whole-of-lease issues
- improved establishment of floristic diversity through better topsoil handling and seeding methods
- better liaison with stakeholder groups, particularly NGOs
- the importance of assessing cumulative impacts and integrating mining proposals into bio-regional contexts and land use planning processes

- greater recognition of the importance of monitoring and research programs that will enable continuous improvement
- recognition that biodiversity and its rehabilitation is not simply a case of 'do and forget' and require management solutions which ensure that the values existing at mine closure are sustained or enhanced.

Integration of the precautionary principle in a consistent manner in relation to biodiversity management is also an opportunity for improvement. It is anticipated that this handbook will help provide the tools and encouragement necessary to enable many more companies to adopt the leading practice biodiversity management standards described.

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FURTHER READING AND WEBSITES

Biodiversity Hot Spots

- www.biodiversityhotspots.org

Department of Industry, Tourism & Resources www.industry.gov.au

- *Leading Practice Sustainable Development Program* www.industry.gov.au/sdmining
- *MCMPR* www.industry.gov.au/resources/mcmpr

Department of the Environment and Heritage www.deh.gov.au

- *Sustainable Minerals Series*
www.deh.gov.au/settlements/industry/minerals/index.html
- *State of the Environment Reporting*
www.deh.gov.au/soe/themes/biodiversity/index.html
- *National Water Quality Management Strategy*
www.deh.gov.au/water/quality/nwqms/

Environmental Legislation in Australia

- Australian Government - www.deh.gov.au
- New South Wales Government - www.environment.nsw.gov.au
- Queensland Government - www.epa.qld.gov.au
- South Australian Government - www.epa.sa.gov.au
- Tasmanian Government - www.dtae.tas.gov.au
- Victorian Government - www.epa.vic.gov.au
- Western Australian Government - www.epa.wa.gov.au
- Northern Territory Government - www.nt.gov.au
- Australian Capital Territory Government - www.environment.act.gov.au

Equator Principles

- A Benchmark for the Financial Industry to Manage Social and Environmental Issues in Project Funding www.equator-principles.com

International Council on Mining & Metals www.icmm.com

- *ICMM Sustainable Development Principles*
www.icmm.com/icmm_principles.php
- *Good Practice Guidance for Mining and Biodiversity*
www.icmm.com/library_pub_detail.php?rcd=195

- ICMM, July 2005a, *Biodiversity Offsets: A Proposition Paper*
www.icmm.com/library_pub_detail.php?rcd=185
- ICMM, July 2005b, *Biodiversity Offsets: A Briefing Paper for the Mining Industry*
www.icmm.com/library_pub_detail.php?rcd=186

Millenium Ecosystem Assessment

- Ecosystems and Human Well-being: Opportunities and Challenges for Business and Industry <http://www.maweb.org/en/Products.aspx?>

Minerals Council of Australia www.minerals.org.au

- *Enduring Value* www.minerals.org.au/enduringvalue

GLOSSARY

Baseline studies	Studies undertaken to describe the conditions that exist before an action is taken.
Benthic	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Biodiversity	The variety of life on our planet, measurable as the variety within species, between species, and the variety of ecosystems. <i>See Section 2.1 of this booklet for a full definition.</i>
Biodiversity offsets	Conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure no net loss of biodiversity.
Bioindicators	A biological parameter (or a value derived from a biological parameter) which provides information about an environmental phenomenon.
Biosecurity	Protection of the biological integrity of an area through exclusion of introduced pests, weeds and diseases.
Closure	A whole of mine life process which typically culminates in tenement relinquishment.
Cumulative impacts	Two or more individual effects which, when considered together, compound or increase the impact.
Degradation	A loss of condition and capacity to provide for desired uses and values, either now or in the future.
Deoxygenation	The act or operation of depriving of oxygen.
Ecosystem Function Analysis (EFA)	A procedure used by some mines to assess ecosystem function and recovery following disturbance. The three components of EFA are Landscape Function Analysis, Vegetation Dynamics and Habitat Complexity.
Environmental Management System (EMS)	A tool for managing an organisation's impact on the environment. It provides a structured approach to planning and implementing environmental protection measures.
Endemic species	Native plant or animal restricted to a specific locality or geographic region.
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The EPBC Act protects the environment, particularly matters of National Environmental Significance. It streamlines national environmental assessment and approvals process, protects Australian biodiversity and integrates management of important natural and cultural places.

Habitat fragmentation	The breaking up of a habitat into unconnected patches interspersed with other habitat which may not be inhabitable by species occupying the habitat that was broken up.
Hyporheos	Organisms inhabiting subsurface waters in a stream bed.
Interstices	The tiny spaces within streambed sediments.
Leading practice	Best available current practice promoting sustainable development.
Local provenance	Plants whose native origin is close to that where they are going to be planted (for example in the same local area).
Macroinvertebrates	Animals without backbones which can be seen with the naked eye.
Mycorrhizal associations	Specialised beneficial associations between a fungus and a plant root system.
Minerals Industry	The minerals industry can be defined as encompassing the exploration, extraction, processing (crushing, separation), smelting, and other processing of metals and minerals. It does not generally include the downstream manufacture of consumer goods from these materials. While not a mineral in the strictest sense, the mining and processing of coal is commonly included within the definition of the minerals industry.
Niche	The full range of biological and physical conditions under which an organism can live and reproduce.
Phreatophytic species	Any plant species that obtains a significant portion of the water that it needs to survive from the zone of saturation or the capillary fringe above the zone of saturation.
Phytosanitation	The treatment of equipment and materials to assist in the prevention of pests and pathogens.
Precautionary principle	If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
Recalcitrant species	Species that are difficult to re-establish.
Recolonisation	A second or renewed colonisation after a dislodgement.
Rehabilitation	The return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounding land.
Relinquishment	Formal approval by the relevant regulating authority indicating that the completion criteria for the mine have been met to the satisfaction of the authority.

Remnant vegetation	Native vegetation remaining after widespread clearing has taken place.
Riparian	Pertaining to, or situated on, the bank of a body of water, especially a watercourse such as a river.
Somatic embryogenesis	The process of embryo initiation and development from vegetative or nongametic cells.
Stakeholder	A person, group or organisation with the potential to be affected by the process of, or outcome of, mining operations.
State of the Environment (SoE) Reporting	SoE reporting occurs at both the national and state/territory level. SoE Reports provide information about environmental and heritage conditions, trends and pressures for the Australian continent, surrounding seas and Australia's external territories.
Succession	The natural process of community change that culminates in the development of the climax community of the area.
Tissue culture	A method of asexual propagation used to produce clones of a particular plant in large quantities.

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