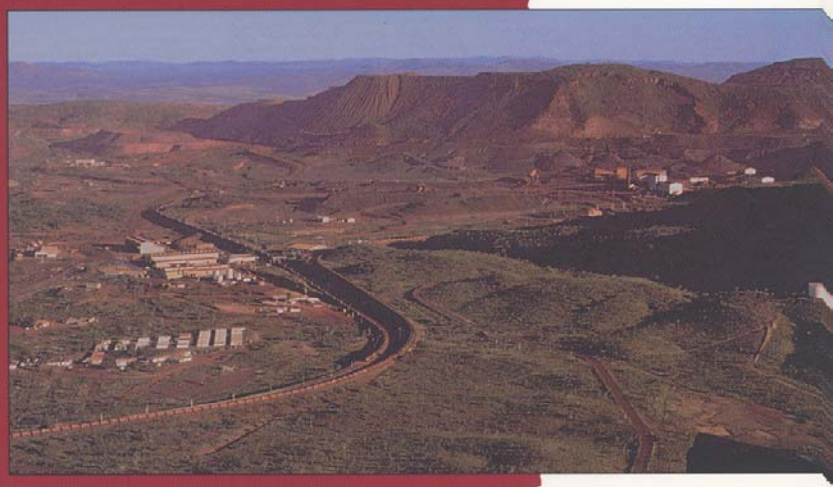
BEST PRACTICE
ENVIRONMENTAL
MANAGEMENT
IN MINING

Overview of Best Practice Environmental Management in Mining



Environment Australia

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The series illustration of the Koalas by Christer Eriksson was commissioned by BHP Billiton Transport. Reproduced courtesy of BHP Billiton Transport

Cover photo: Mining of iron ore, Hamersley Range, northern Western Australia. Minimising environmental damage by improving environmental planning, management and rehabilitation throughout the mining and energy industries, and communicating the industries' environmental achievements to the public, is an important part of achieving ecologically sustainable development. *Photo courtesy DFAT*

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Environment Australia incorporates the environment programs of the Federal Department of the Environment and Heritage.

Overview of Best Practice Environmental Management in Mining

One Booklet in a series on

BEST PRACTICE ENVIRONMENTAL MANAGEMENT IN MINING

Strip mining of coal using draglines moves very large volumes of overburden and poses significant challenges for land rehabilitation and post-mining void management. The mine site is about 5 km wide by 20 km long. Goonyella mine (BHP Billiton Coal Pty Ltd), central Queensland, April 2001. Photo: Stewart Needham

Environment Australia

August 2002

FOREWORD

Protecting the environment is a priority for all members of our society. Governments have a key role in setting environmental standards and ensuring that individuals and organisations meet them. Increasingly, however, governments, industry and community organisations are working as partners to protect our environment for present and future generations.

Representatives of the minerals industry in Australia and Environment Australia, (the environment arm of the Federal Government), are working together to collect and present information on a variety of topics that illustrate and explain best practice environmental management in Australia's minerals industry. This publication is one of a series of booklets aimed at assisting all sectors of the minerals industry to protect the environment and to reduce the impacts of minerals production by following the principles of ecologically sustainable development. It should be of value to practitioners involved in exploration and planning through to supply chain and minerals processing.

These publications also provide information that allows the general community to gain a better appreciation of the environmental management practices applied by the minerals industry.

Our best practice booklets include examples of current best practice in environmental management in mining from some of the leaders in the Australian industry. They emphasise practical, cost-effective approaches to protecting the environment that exceed the requirements set by regulation. Case studies are provided to encourage better environmental performance in Australia and internationally. These case studies demonstrate how best practice can be applied in diverse environments across Australia, while allowing flexibility for specific sites.

The concept of best practice is simply the best way of working sustainably at a given site. The booklets integrate environmental issues and community concerns through all phases of mineral production, providing:

- Basic principles, guidance and advice;
- Case studies from leading Australian companies; and
- Useful references and checklists.

We encourage mine managers and environmental officers to take up the challenge to continually improve environmental performance and management of our global resources and to apply the principles outlined in these booklets.

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EXECUTIVE SUMMARY

Today's modern society places ever-increasing demands upon the supply of raw materials necessary in the provision of infrastructure, services and goods for national development. A large proportion of these raw materials are obtained by mining. As low-cost ore deposits are not evenly distributed around the world because of geological differences, and as efficient, large-volume transport facilities are now available to every country, mining has become a truly global activity. Ore mined in one country may be exported to another for refining, and exported to a third country for fabrication into the final product which may then be sent for sale to consumers in yet more countries.

Australia is one of the few developed countries that are heavily dependent upon mining for its economic wellbeing. Mineral and energy exports currently constitute 47 per cent of Australia's merchandise exports and 37 per cent of total exports including services, and have contributed more than $A 500 billion to the national wealth over the past 20 years. As well, roughly $A 2 billion a year is earned from the export of high-technology mining products and services. Mining is also a large employer, and has been a major impetus for development with many towns, roads, railways, ports and airports as well as industries owing their existence wholly to mining. A large number of technological innovations in mining such as extraction techniques, mineral separation and smelting have been developed here, and in recent decades Australian companies have become active in mineral exploration and mining in many countries around the world. It is true to say that Australia has been and still is a world leader in mining technology.

Old Mine and Open Shaft - Early mine operations still have an impact on the surrounding environment
Photo Courtesy Outback Ecology

As the scale of mining activity has increased, as well as the infrastructure to support it, so has the level of impact upon the environment. The 1950s and 1960s were a turning point for attitudes into the impacts that industry in general and mining in particular were having on the environment. Part of the reason for this change in attitude was the obvious damage being caused to the environment from mining activities such as direct discharge of tailings into rivers, periodic flooding and escape of acid mine water, collapse of tailings and waste rock piles, and contamination of soils and the food chain from heavy metals and other compounds. Such impacts from mining in the early to mid 20th century are evident around the world, including Australia.

Since the 1960s, more enlightened attitudes about the values of the environment to social and economic health have brought many older types of mining practice into direct conflict with the standards now required by regulators and the general public. The viability of the mining industry is challenged because of high expectations for

environmental protection, lower risk to human health, competing land use demands, and the value of the natural environment as recreational space, and as the repository of valuable biological assets, natural environmental services and aesthetic appeal.

Mining practice has evolved to reflect these concerns and regulatory requirements, and some operators have introduced management policies and practices and have adopted technologies that allow mining to occur with minimum environmental harm. However, it is clear from such instances as the Baia Mare cyanide spill in Romania in January 2000 and the tailings dam collapse at Los Frailes in Spain in April 1998 that mining activities still pose risks of significant environmental harm and that there is room for improvement in the standard of environmental protection policies, management systems and technologies applied at many mine sites.

Present-day attitudes to environmental protection are represented in the development of the concept of sustainable development, of "triple bottom line accounting", of cleaner production, of life-cycle assessment to assess potential impacts, of the precautionary principle as defined in the *Environment Protection and Biodiversity Conservation Act 1999*, and of environmental impact assessment to advise decision-makers and the broader community on the potential negative as well as positive outcomes of a proposed development. All of these are relevant to the mining industry, and extend from the pre-mine planning phase, through construction, mining, and mine closure to post-mine stewardship.

This series of booklets on Best Practice Environmental Management in Mining was devised by the Australian Government to help improve the level of understanding of how these concepts can be applied to the mining industry, and to provide practical advice on management and operational methods to reduce the level of environmental harm from mining to acceptable levels. It has been developed in collaboration with the Australian mining industry, and in consultation with key stakeholder groups. Booklets on individual key topics are written by leaders in the field and peer edited by industry, community and government sector experts to ensure their relevance, currency, and clarity.

The booklets are not designed to provide a framework for regulation and are written for both specialists and non-specialists. Checklists are available for each booklet topic to assist mine operators and regulators in determining whether a mine site is being managed and operated in a manner consistent with best practice.

Over twenty booklets are available on topics covering mine planning, operations and closure, dealing with management policies, objectives and systems, design principles, operational systems and technologies, monitoring, staff training and stakeholder interaction. The booklets are incorporated as key source materials in the Environment Australia/UNEP Best Practice Environmental Management in Mining Training Kit. Translations of nine booklets are available in Spanish, Mandarin Chinese and Bahasa Indonesia (see Table 1). This Overview booklet briefly summarises the topics covered by, and the key message or recommendations in, each booklet.

The mistakes of the past, such as pollution caused by these old dumps at Captains Flat, New South Wales (shown in 1974 before remedial works) are being avoided because of awareness of the need for environmental protection, and improved practices. Photo: Graeme McIlveen

The benefits of best practice include preventing harmful environmental and social impacts, improved access to land for mineral exploration, greater certainty of outcomes in the project application stage, lower risk of non-compliance, greater acceptance/less resistance from key stakeholders (in particular local communities and land owners), lower financial burdens in the mine closure and rehabilitation phases, and lower risk of significant liabilities post-closure.

Best practice methodologies make up about 5 per cent of the capital and operating costs for new mining projects. However, these costs can commonly be offset against the many benefits that best practice brings. The cost of cleaning up a major spill for example can exceed the annual budget for good environmental practice at a site by a factor of 10 to 100 or even more. Moreover, best practice energy and water management can routinely yield significant financial savings.

Costs of environmental management are commonly lower when measures are incorporated at the planning stage instead of retrofitting and redesigning systems later in the life of the mine. Whilst it is not easy to quantify the costs of best practice, it is easy to see that the up-front costs of incorporating best practice into a mining operation reaps long term gains for the individual project in terms of regulatory performance and lower potential liabilities. At the broader level, widespread adoption of best practice environmental management techniques will translate into long term gains for the industry through greater certainty for access to land and project approvals, improved relationships with regulatory authorities, acceptance by the community, and lower levels of risk to the environment.

Table 1. Titles in the BPEM Booklet Series, and Those Translated into Other Languages

Title	Translated into Spanish, Mandarin Chinese and Bahasa Indonesia (note: the Bahasa Indonesia and Spanish translations are also available on line)
Mine Planning for Environmental Protection	Indonesian booklet Spanish booklet
Community Consultation and Involvement	Indonesian booklet Spanish booklet
Environmental Impact Assessment	Indonesian booklet Spanish booklet
Environmental Management Systems	Indonesian booklet Spanish booklet
Planning a Workforce Environmental Awareness Training Program	Indonesian booklet Spanish booklet
Cleaner Production	
Energy Efficiency	
Environmental Risk Management	
Onshore Minerals and Petroleum Exploration	
Tailings Containment	Indonesian booklet Spanish booklet
Hazardous Materials Management, Storage and Disposal	
Managing Sulphidic Mine Wastes and Acid Drainage	
Water Management	
Noise, Vibration and Airblast Control	
Cyanide Management	
Dust Control	
Atmospheric Emissions	
Environmental Monitoring and Performance	Indonesian booklet Spanish booklet
Environmental Auditing	
Rehabilitation and Revegetation	Indonesian booklet Spanish booklet
Landform Design for Rehabilitation	
Contaminated Sites	
Mine Decommissioning	

CONTENTS

1 INTRODUCTION

At the International Association of Impact Assessment (IAIA) meeting in Ottawa in 1994, attended by representatives from the World Bank, the United Nations Environment Programme (UNEP) and other international agencies, Australia was asked to take the lead in showcasing examples of best environmental practice in all aspects of the mining industry.

In response to this request the Australian Government's environment department, Environment Australia, formed a partnership with the Australian mining industry to identify and develop products on best practice environmental management in mining. The partnership is guided by a stakeholder representative steering committee with members drawn from individual mining companies (currently WMC, Rio Tinto, BHP Billiton Coal and Newmont Australia), the Minerals Council of Australia, government departments with responsibilities for mining and technology (NSW Department of Mineral Resources), research organisations (CSIRO, Geoscience Australia), and non-government organisations with specific interests in mining (Mineral Policy Institute). Environment Australia and a mining industry representative chair this steering committee jointly.

The objectives of the booklets are to:

- Demonstrate examples of best practice environmental management in the Australian mining industry;
- Promote Australia's experience and expertise across all phases of mining, from mine environmental planning, impact assessment, environmental management, stakeholder communication, and mine closure; and
- Assist the mining industry and communities internationally by providing benchmarks for environmental performance and access to Australian expertise.

Funding has been shared between government and industry: recurrent funding is provided mainly from Environment Australia; while industry has provided sponsorship funding for the production of specific booklets, provided authors at reduced or no cost for many booklets, provided expertise to the technical review panel, and met the costs of steering committee members.

This program now forms part of a larger Environment Australia program developed in 1999 to promote sustainability across all industry sectors. Information on this wider program is available at www.ea.gov.au/industry/index.html.

Over twenty booklets have been published, each one describing best practice for a particular key aspect of environmental management as currently applied by Australia's leading environmental managers in mining. These booklets have been available in hard copy and from 1995 to 2000 have been distributed to over sixty countries around the world. Nine titles were translated into Spanish, Bahasa Indonesian and Mandarin Chinese to assist distribution into regions where Australian companies are particularly active in exploration and mining (ie southeast Asia and South America).

Application of best practice environmental management as represented in these booklets will lead to enhanced environmental performance, whilst maintaining competitiveness.

Many of the Australian examples in the booklets may not be directly applicable to different environmental, social, economic or technical situations in other countries. However, Australia is keen to share its knowledge in environmental management in mining with the rest of the world to improve the level of information available on best practice alternatives, and to assist other countries in developing solutions appropriate to their specific circumstances. An important component of best practice is the ability to be flexible in devising solutions which match site-specific needs in terms of the types of mining operation, climate, topography, the sensitivity of the surrounding environment, and social requirements, which deliver outcomes consistent with sustainable development principles and objectives.

Exchange of information on alternative ways of achieving sustainable development objectives will help improve the overall level of performance by the industry globally and advance the standing of the mining sector as an environmentally responsible industry.

The BPEM booklets represent the first concerted effort to benchmark environmental performance across a broad range of issues in the Australian mining industry, with a view to lifting performance by all practitioners to these benchmarks, and encouraging further improvements by leading companies.

The benchmarking approach in the BPEM booklets is consistent with moves by industry to assume greater levels of responsibility for environmental protection, such as establishing voluntary codes of practice [eg Australian Minerals Industry Code for Environmental Management; Australian Petroleum Production and Exploration Association Code of Environmental Practice, and investigating major issues affecting public and government sector concerns and perspectives on mining under the Global Mining Initiative. The booklets are not designed to provide a framework for regulation, although they do provide information to regulators and key stakeholders on different possible approaches to achieving high levels of environmental protection. A key objective is to encourage operators to strive for levels of environmental protection which are greater than those required by regulation, to reduce the probability of non-compliance, and to lower levels of harm to the environment in the event of non-compliance.

International access to the resources developed by the BPEM in Mining program include:

- The booklets are available free of charge on the *internet*. Follow the links provided in this document.
- A series of *Checklists* – one for each booklet -- which provides simple, step-by-step guidance to inform mining operators on how to adopt best practice management and operational techniques. The checklists are aimed in particular at small to medium-scale operations, which do not have on-site environmental expertise and lack the budget to purchase the services of environmental consultants. The checklists also provide assistance to regulators and industry on how assessments of performance in a best practice context can be made.
- The joint Environment Australia/UNEP Best Practice Environmental Management in Mining *Training Kit* is a valuable resource for trainers to design and deliver courses and workshops on major topics in mining. The BPEM booklets are an integral part of the training kit as they represent key source material.

Best practice environmental management in mining focuses on the principles of environment impact assessment and environmental management. The booklets use case studies to demonstrate how these principles can be integrated through all phases of resource development from pre-exploration planning, through construction, operation, closure and post-mining monitoring and maintenance.

The booklets are written for both specialists and non-specialists. They are targeted at managers to provide the practical techniques and guidance they need to manage the environmental risks and impacts of their own operations. The use – as far as practicable – of non–specialist language should allow stakeholders with a general interest in mining, or concerns about a particular mine site, to understand the general issues involved in environmental management and allow them to communicate more effectively with industry and regulatory officials. The booklets are also a valuable resource for students in mining courses, in general and mining-specific environmental courses, and for educators as source materials. Many aspects of the booklets are equally relevant to other industry sectors and may be used by them in the absence of any specific environmental management best practice materials relevant to their own industry activities.

2 THE RESOURCE SECTOR IN AUSTRALIA

The mining and energy industries are important components of the Australian economy. The resource sector is one of Australia's largest export earners and is a direct or indirect employer of about half a million Australians. In 2000-2001 the value of Australia's mineral and petroleum exports was $A 55.5 billion, amounting to 47% of merchandised exports. Direct contributions to Gross Domestic Product have been about 9% for the past decade. As well as generating export income, the resources sector provides the raw materials needed for many of the consumer goods used by Australians each year and most of the energy used for power generation, industry and domestic purposes.

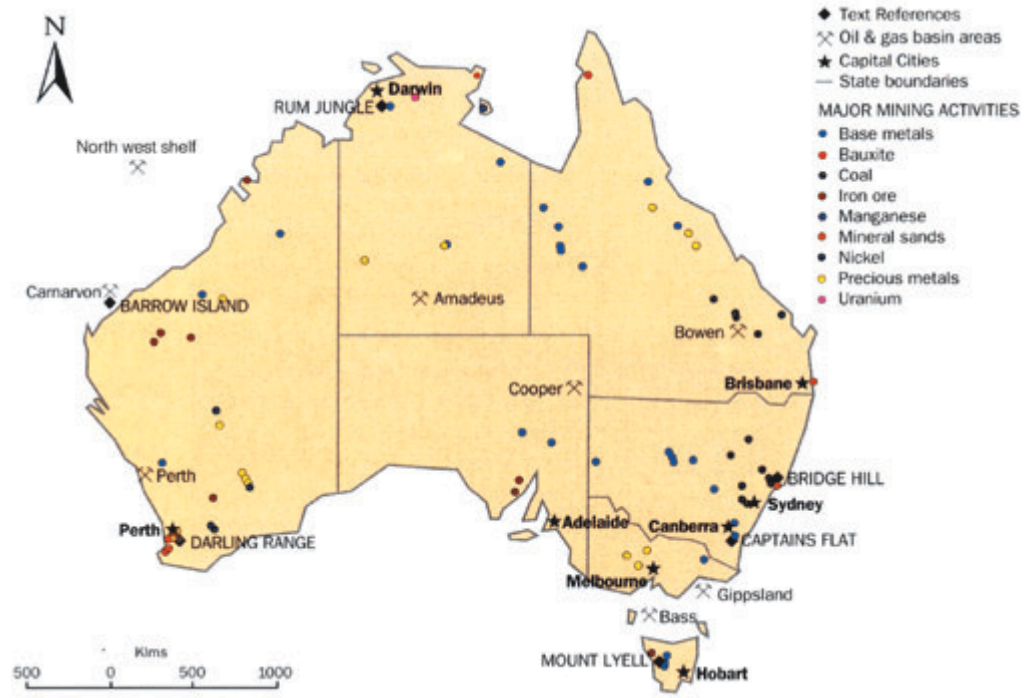


Figure 1. Selected mines and petroleum production areas of Australia

Australia is among the top three producers for many of the world's most important minerals. It is the leading producer of bauxite, diamonds, ilmenite, rutile and zircon and the second biggest producer of uranium; the largest exporter of black coal, alumina, diamonds (by volume) and mineral sands products; the largest exporter of iron ore, the second largest exporter of lead, the third largest exporter of zinc, and the third largest exporter of aluminium metal. It is also a significant producer of gold (fourth largest) and copper (seventh largest) (ABARE 2001).

Outback Town and Mine - Mine operations are conducted in a wide range of climatic conditions. Photo Courtesy Outback Ecology

Australia also extensively exports its technical expertise in mining. Australian mine planning software is used by at least 70% of all large mines around the world. Export of intellectual property now exceeds $A1 billion annually, including technologies such as advanced electronic blasting, Atomic Absorption Spectroscopy, aluminium smelter innovations, Becher process, bioheap bacterial leaching, HISmelt, SIROSMELT, Jameson Flotation Cell, and robotics processes.

The mining and energy production industries in Australia include all types of operations in many different climatic zones. Some of the major activities (Figure 1) are:

- Open cut mining for bauxite, iron ore, coal, gold, nickel, uranium and diamonds;
- Underground mining for coal, gold, silver, copper, lead, uranium and zinc;
- Dredging for mineral sands; and
- Onshore and offshore oil and gas production.

Mining is conducted in climatic conditions ranging from the wet temperate areas of western Tasmania, to Mediterranean areas of southwest Western Australia, tropical parts of northern Australia, the sub-tropics of Queensland and northern coastal New South Wales, temperate Victoria and southern New South Wales, and the dry grassland to arid desert interior.

Mining of iron ore, Hamersley Range, northern Western Australia. Photo courtesy DFAT

The natural vegetation types in mining areas include rainforest, forest, woodland, heaths, wetlands and grasslands. Pre-mining land uses include grazing, cropping, rural-residential and urban development, forestry, water catchment, conservation, recreation and traditional indigenous uses.

The ownership of Australia's mineral resources is vested in the Commonwealth Government and State and Territory Governments on behalf of the Australian people. Exploration and mining leases are issued to mining companies by governments on behalf of the community. While individual governments in Australia differ in the processes and terminology they use, there are no significant

differences in the levels of performance required to meet conservation, environment protection, and development objectives throughout Australia.

3 MINING AND ECOLOGICALLY SUSTAINABLE DEVELOPMENT

Governments and the mining industry in Australia have embraced the concept of sustainable development as defined in the Brundtland Report (World Commission on Environment and Development, 1987), ie "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". The concept was further refined at the 1992 Rio Earth Summit, which retained a commitment to ecological integrity but also incorporated social and economic dimensions of sustainability (view Earth Summit 1992 documents).

Sustainable development may be seen as maintaining and enhancing:

- natural capital, defined as all natural resources including environmental attributes and those of traditional economic value;
- manufactured capital, that is made by human kind, including produced goods, infrastructure and the built environment;
- human capital, defined as the health, well-being, intellectual capabilities and spiritual welfare of individuals; and
- social capital, defined as social relations and institutions within and between societies, and their norms and functionalities.

The Australian Government recognises the fundamental importance of the health of the natural environment as an underpinning to future economic, social and ecological well being, and has developed a strategy entitled the *National Strategy for Ecologically Sustainable Development*, or ESD (Commonwealth of Australia 1992). The goal of ESD is to achieve development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which all life depends. The objectives of ESD are to:

- enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- provide for equity within and between generations; and
- protect biological diversity and maintain essential ecological processes and life support systems.

The challenge for government and the mining industry stated in the national strategy for ESD is "to develop further the mining industry and efficiently manage the renewable and non-renewable resources on which it depends, in accordance with the principles of ESD". Governments are committed to achieving this by pursuing a number of strategic approaches and initiatives to ensure that sound environmental practices are used and promoted throughout all sections of the mining industry.

The *precautionary principle* is a major component of ESD that underlies the Australian mining industry's environmental protection approach to efficient management of the renewable and non-renewable resources on which it depends. Its application by the Australian mining industry takes the form of:

- adoption by companies of external and internal codes of practice, guidelines, standards and principles for exploration, environmental management, rehabilitation and community relations activities;
- comprehensive study, planning, evaluation and development of project proposals;
- extensive consultation with government, landowners and community groups;
- objective and comprehensive environmental impact and risk assessment of projects;
- comprehensive environmental management systems;
- commitment to continual improvement;
- commitment to the pro-active identification and minimisation of environmental impacts, and less reliance on "end of pipe" solutions (ie adoption of cleaner production concept);
- development and support of generic and site-specific research and development programs on technologies and techniques to improve the effectiveness and efficiency of environmental protection measures; and
- industry environmental review, education and knowledge-sharing networks.

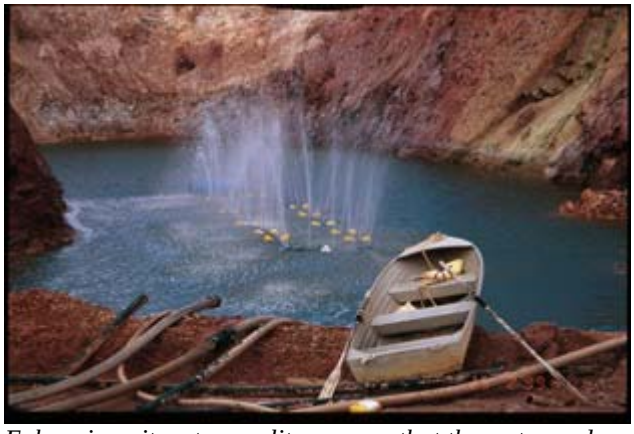
> "The *precautionary principle* is that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage". (*Environment Protection and Biodiversity Conservation Act 1999*).

Accompanying strategies that are necessary components of ESD are:

- integration of long and short term economic, environmental, social and equity goals in policies, actions and activities;
- ensuring that environmental assets are appropriately valued;
- gaining involvement and prior informed consent of communities regarding all decisions and actions that affect them;
- developing environmentally sound international competitiveness and an economy that can enhance environmental protection; and
- recognising the global dimension of the environment and impacts on it.

The publication of these booklets demonstrates the commitment of the Australian Government and the mining industry to achieving ecologically sustainable development through best practice environmental management in mining. This project is part of the Australian Government's promotion to improve the efficiency and effectiveness of renewable and non-renewable resource use, including the extraction and use of mineral resources, the consumption of energy and water, and minimising the level of harm to ecosystems.

As an international leader in mining, minerals exports and mining technology, it follows that Australia should also strive to be a leader in developing and demonstrating how mining can be undertaken without causing unacceptable levels of environmental and social impact. This leadership will assist Australian companies in gaining access to mining projects internationally, and allow information on best practice to be shared with the mining industries of other countries so that mining may develop into a recognised globally responsible industry.



Enhancing pit water quality ensures that the water and surrounds are not a source of ongoing pollution or instability
Photo Courtesy Outback Ecology

4 MINING AND THE ENVIRONMENT

When minerals and energy resources were being developed and exploited over forty years ago, environmental issues were not a major consideration for the resources sector or the community. However, the community now expects the resources sector to apply high standards of environmental management to all projects.

The community expects and demands that the mining industry integrates environmental considerations into every development, even at sites remote from settlement. It also expects that no legacy of environmental damage is left after mining ceases, and that no liability is transferred to it or the government for the costs of repairing environmental damage or restoring the mined area to a safe condition which may be suitable for some subsequent beneficial land use. Increasingly, industry is accepting responsibility for and demonstrating that it can protect the environment during and after mining operations.

Examples of severe environmental degradation, such as those associated with the long-closed Rum Jungle uranium-copper mine in the Northern Territory and the Mount Lyell mine in northwest Tasmania, where copper has been mined for over 100 years, remain as powerful images of past performance which is not acceptable today. Mining as an activity which renders the land unsuitable for any subsequent use is no longer a valid concept; the "user pays" principle ensures that those that profit from mining are now held liable for any negative impacts the mining activity has on surrounding areas and its peoples.

Mt Lyell, Queenstown, Tasmania. Lack of vegetation and soil cover on surrounding hills is due to logging for fuel roasting furnaces and effects of resulting sulphurous fumes. Intense rainfall has lead to massive soil erosion into the Queen river. Photo courtesy The Mt Lyell Mining & Railway Co. Ltd.

Mining has been a major activity in Australia for 150 years, and examples of environmental damage from the old mining activities are numerous. Governments conduct small ongoing programs to rehabilitate these old sites, but much of the progress in this area is associated with new exploration and mining phases at some of the old sites (eg to develop lower grade and deeper ores which were uneconomic for the smaller-scale operations of the past); development approvals commonly include requirements for rehabilitation works to include the old disturbed areas as well as the newer ones. Ecosystem rehabilitation is a relatively new science, even though humans have been disturbing the land for centuries. In *Biodiversity, Australia's Living Wealth*, (Beattie 1995) it is noted that Australia is leading the

world in many aspects of rehabilitation technology, especially for mine sites. Mining organisations are developing the expertise to re–assemble species into communities that have a chance to grow, develop, and rebuild local biodiversity [biodiversity, or biological diversity, is the full variety of living forms – plants, animals and micro–organisms – their genetic make-up, the different species, and the ecosystems of which they are part]. Good planning and environmental management will minimise the impacts of mining on the environment and will help to preserve this diversity. This is particularly important where there may be impacts on rare or endangered species of plants or animals.

The mining and energy industries in Australia have a great deal of expertise in environmental planning, management and rehabilitation. A number of areas mined and then rehabilitated are now included in National Parks. For example, Bridge Hill Ridge in central New South Wales, once mined for mineral sands, has been included in the Myall Lakes National Park. The Ranger uranium mine in the monsoonal part of the Northern Territory is being managed to exacting standards to ensure that the high ecological values of the World Heritage-listed Kakadu National Park and its extensive wetlands immediately adjacent to the mine are not threatened (www.ea.gov.au/ssd/index.html).

Alcoa of Australia Ltd has won international recognition for its work in rehabilitating bauxite mines on the Darling Plateau southeast of Perth in Western Australia. For performance and expertise, it is listed on the United Nations Global 500 Roll of Honour for Environmental Achievement – the only mining company in the world to be recognised in the manner. In an outstanding example of mine rehabilitation for beneficial community use, sand and aggregate quarries operated by three different companies (Boral, CSR and Pioneer International) over a 2000 hectare area west of Sydney were rehabilitated to a series of public parklands and waterways, including an international rowing facility which was the venue for rowing at the 2000 Olympics.

Beenup Wetland - Rehabilitation throughout the mining and energy industries is an important part of achieving ecologically sustainable development. Photo Courtesy Outback Ecology

Environmental expertise within the Australian energy industry is demonstrated in the development of the oilfield on Barrow Island off the Western Australia coast. Conservation values of the island, which is an ‘A’ Class Reserve for the protection of flora and fauna and one of Australia's most important wildlife refuges, remain despite more than thirty years of exploration and oilfield development. The low impact exploration techniques developed by Western Australian Petroleum Pty Ltd are recognised as a benchmark for environmentally sensitive exploration internationally and received an AMEEF Environmental Excellence Award in 1994.

Minimising environmental damage by improving environmental planning, management and rehabilitation throughout the mining and energy industries, and communicating the industries' environmental achievements to the public, is an important part of achieving ecologically sustainable development. Some mining companies demonstrate their commitment to environmental protection by participating in or initiating environmental restoration projects related to non-mining impacts in partnership with local communities. An example is the Arid Zone Recovery project, which is a joint venture between WMC Ltd, State Government, a University environment department, and a local community group. The objective is to restore 60 square kilometres of arid zone land north of the Roxby Downs copper-gold-uranium mine degraded by over-grazing and the impact of feral animals, to a pre-European condition. Feral pests have been eliminated, and cat-, rabbit- and fox-proof boundary fences erected. Old mining equipment is recycled for fence posts, erosion control and shelters for native animals that have been re-introduced. A range of innovative technological approaches is developing transferable and cost-effective wildlife management solutions, and the project provides training for secondary and tertiary students.

4.1 POTENTIAL IMPACTS FROM MINING

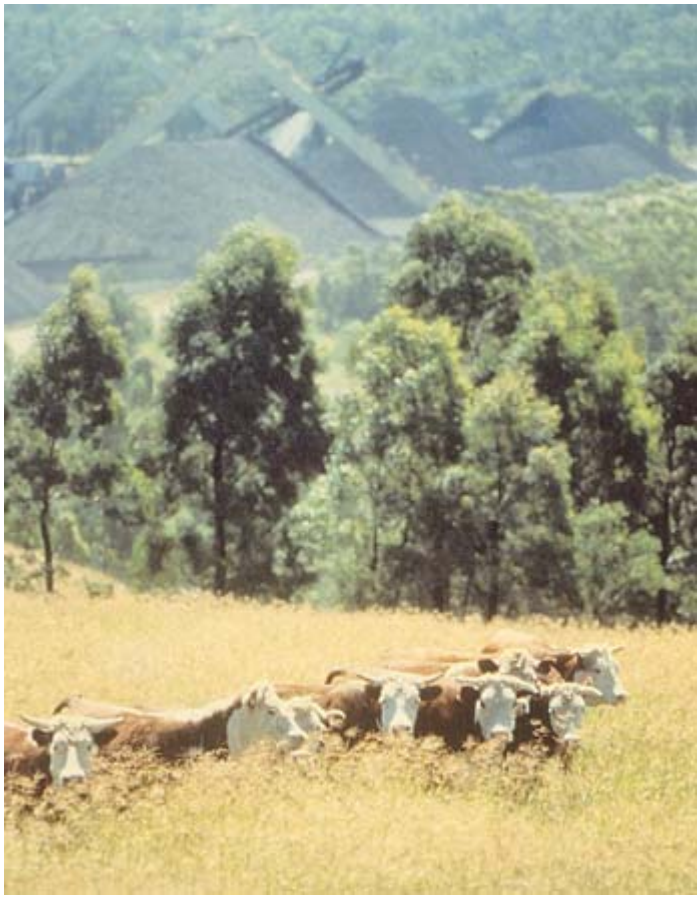
Successful environmental management in the resources sector is dependent on recognising, and avoiding or minimising, environmental impacts. Protection of the environment requires careful planning and commitment from all levels and groups within a mining company. Best practice environmental management in mining demands a continuing, integrated process through all phases of a resource project from the initial exploration, through construction, operation, decommissioning and closure. Mining and energy extraction, and associated processing, have the potential to cause a number of environmental problems if projects are not properly planned and managed.

Potential problems include:

- Wind and water erosion (erosion may increase sediment loads and decrease water quality in streams, reduce the productivity of the soil and create a dust nuisance);
- Contamination of surface or ground water by sediment, mobilisation of salt, release of toxic elements from overburden, tailings or wastes, or spills of oil, chemicals or fuel as surface runoff or as underground seepage;
- Changes to surface and ground water flows and levels;
- Damage to soils including salination, acidification, pollution and compaction or loss of soil structure;
- Dust or noise nuisance, vibration and a reduction of visual landscape values;
- Generation of tailings and other wastes that may release toxic elements or be mobilised by erosive forces;
- Gaseous emissions from mineral processing, methane emissions from mine openings, fumes from coal seam fires;
- Possible sudden failure of engineered containment structures such as tailings dam embankments, settling and holding ponds, resulting in release of high concentration/high volume contaminants;
- Acid mine drainage (tailings, ore and waste dumps, and old mining areas which contain sulphur or sulphides such as iron sulphide, can generate acid through bacterial oxidation when exposed to moisture and oxygen - this acid

leachate may then mobilise heavy metals that can be released into the environment;

- Loss of flora including direct losses through clearing and indirect effects due to the spread of plant pathogens and weeds;
- Loss of fauna including direct losses through vegetation clearing and the indirect effects on species through the reduction and fragmentation of habitat and the introduction of feral animals;
- Damage to heritage sites; and
- Destruction of adjacent habitats arising from the development of camps, towns and services stimulated by the mining project.



Hunter Valley No 1 Mine, Singleton New South Wales – cattle grazing on land rehabilitated after open cut coal mining. Photo: Coal and Allied Operations

Mining and energy extraction may also have substantial social impacts and lead to land use conflicts, difficulties in relationships with neighbours and local communities, and debate on resource use issues. Many of the land use conflicts can be managed by recognising that mining and energy extraction are temporary land uses that may be integrated with many (but not all) current or future land uses. The potential for these impacts to occur can be minimised by improving environmental planning, management and rehabilitation knowledge and techniques. Some land use conflicts can be managed by recognising that mining and energy extraction are temporary land uses that can be integrated with a current or future land use. Initiating community consultation programs and taking account of community needs can improve relationships with neighbours and local communities.

In order for the capacity for effective environmental protection to improve and spread through the mining and energy industries, information on environmental issues and effective techniques to address them must be readily available to mining industry staff at all levels, including executive managers, environmental managers

and all other employees. The same information should also be available to the affected communities to ensure they are adequately informed and to build mutual understanding and trust. The BPEM booklets are designed to make information readily accessible to all mining industry staff as well as to interested stakeholders.

4.2 RECOGNISING IMPROVEMENTS IN ENVIRONMENTAL PERFORMANCE

Companies are more motivated to seek out and utilise information on best practice environmental management in mining if they can see evidence that other companies are applying best practice and reaping benefits from it. Other stimuli include formal and public recognition and the rewarding of outstanding examples of best practice. Industry representative bodies can also be very influential by showing leadership in encouraging all mining companies to commit to best practice ideals; eg. by the development of voluntary guidelines, codes, collating information and holding conferences on best practice.

Since the booklet series was begun in 1995, significant developments have taken place in Australia in these areas:

- A wide range of award schemes has developed with a focus on recognising and rewarding environmental excellence in mining, both at the mine site and corporately such as development of environmental policy and environmental reporting (refer to section 9 for details). Some mining companies have also been successful in winning awards in schemes that look for outstanding performance across all industry sectors.
- The http://www.minerals.org.au/ (MCA) has developed a voluntary Code for Environmental Management under which signatories must adopt a range of philosophies and practices, and commit to preparing annual reports of environmental performance, to the completion of an annual survey measuring Code implementation, and to the triennial verification of this survey by an externally accredited auditor. The articles of the Council have been modified to require all members to be Code signatories, and options for strengthening the Code as well as expanding the Code to better incorporate the social dimension are currently being explored.
- The Australian Petroleum Producers and Exploration Association (APPEA) has developed an environmental policy and Code of Environmental Practice and Environmental Guidelines for use by all of its members;
- APPEA also collates information on environmental incidents, environmental research, case studies, and guidance on safety and environmental emergency procedures through its website; and
- MCA and APPEA both run regular environmental workshops to showcase developments and discuss current issues in environmental management in the minerals and petroleum sectors.

Such initiatives as these assist in communicating to stakeholders and the general public the commitment to, and improving levels of high standards of, environmental protection by the Australian mining industry. Improved communication with the general public and special interest groups using objective and independently verifiable information is critical to increasing the level of trust between the industry and the community, and addressing negative perceptions of mining. These negative perceptions are commonly based on past practices that are now illegal and no longer used in Australia. Community consultation and engagement are essential

mechanisms to show that environmental protection and harm minimisation are taken very seriously by today's mining operators. Understanding of the impacts and benefits of mining by the community, and community involvement in all stages of mining from planning, impact assessment, operation and closure, are critical to achieving a platform of ecologically sustainable development for any mining operation.

5 WHAT IS BEST PRACTICE?

Best practice can simply be explained as "the best way of doing things". Best practice environmental management in mining demands a continuing, integrated process through all phases of a resource project from the initial exploration to construction, operation and closure. For it to be successful it requires careful planning and commitment from all levels and groups within a mining company. It is based on a comprehensive and integrated approach to recognising, and avoiding or minimising, environmental impacts. In order to be fully effective, this approach must be based on a sound set of generic and mining specific principles.

The principles of best practice include:

- Ecologically sustainable development;
- Intra- and inter-generational equity;
- Accountability and compliance with international human rights and environmental standards and principles
- The Precautionary Principle;
- Well informed and trained staff;
- Effective communication and openness;
- Flexibility; and
- Continual improvement.

The last two principles recognise that best practice is not fixed in space or time. A best practice technique at one mine may not be suitable at a similar mine elsewhere. Examples include the greater sensitivity of the surrounding environment or different risk factors related to higher rainfall. Continual improvement may be driven by changes in legislative requirements, public expectations, corporate thinking, or by the development of new and improved technology. A technique chosen during mine planning may be found some years later to offer inferior security against environmental harm compared with a newly developed technology. Monitoring may indicate that the desired level of protection is not being met and improved techniques or management methods must be introduced to ensure the standard of protection expected by stakeholders.

Best practice environmental management encompasses every aspect of planning for and operating a mine. This presents problems when designing staff seniority, reporting and responsibility structures. For example, the practice of placing the environmental superintendent within the Engineering Department may have the effect of subsuming the powers and responsibilities of environmental staff to the Engineering Manager who will have conflicting priorities on many issues. This may also limit their scope to only those issues traditionally addressed by the engineering department. It is now common practice for the senior environmental officer to be placed in a separate Environmental Department and report directly to the General Mine Manager to ensure that objectivity and scope of responsibilities are not compromised.

An area disturbed by mineral sand mining from 1974 to 1983 in the New South Wales coastal zone at Bridge Hill Ridge (above, taken in 1976), was rehabilitated and restored to a 120 metre high forested dune (below, taken in 1991). Photos: Yarwood & Associates

The potential scope of environmental issues to be considered, and consequently which fall under the umbrella of best practice environmental management, are reflected in the *Fundamental Principles for the Mining Sector* derived from the "Berlin Guidelines" which were first devised in 1991 and revised in 1999 at the International Round Table on Mining and the Environment in Berlin. The first version of these principles concentrated mainly on the technical and physical aspects of environmental management, while the revision reflects the greater understanding of and concerns for social, community and gender issues which have developed internationally over the last decade.

The principles within best practice, listed above, and the fundamental principles for the mining sector derived from the Berlin Guidelines (see Box 1), demonstrate that best practice depends on a mix of high quality regulation, administrative control and mine management. It is not acceptable for a mining operator to simply conform to regulatory standards without ensuring that those standards will provide adequate protection of the environmental values at the actual mine site. Governments must also share the responsibility of ensuring that their standards, regulations, and staff skills are appropriate to provide reliable assurances to the community that they and their environment are not being exposed to levels of risk they regard as unacceptable.

Box 1 Fundamental Principles for the Mining Sector (Berlin Guidelines 1991 revised 2000)

Governments, mining companies and the minerals industries should as a minimum:

1. Recognise environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management systems. These should include early and comprehensive environmental impact assessments, pollution control and other preventive and mitigative measures, monitoring and auditing activities, and emergency response procedures.
2. Recognise the importance of socio-economic impact assessments and social planning in mining operations. Social-economic impacts should be taken into account at the earliest stages of project development. Gender issues should also be considered at a policy and project level.
3. Establish environmental accountability in industry and government at the highest management and policy-making levels.
4. Encourage employees at all levels to recognise their responsibility for environmental management and ensure that adequate resources, staff and requisite training are available to implement environmental plans.
5. Ensure the participation of and dialogue with the affected community and other directly interested parties on the environmental and social aspects of all phases of mining activities and include the full participation of women and other marginalised groups.
6. Adopt best practices to minimise environmental degradation, notably in the absence of specific environmental regulations.
7. Adopt environmentally sound technologies in all phases of mining activities and increase the emphasis on the transfer of appropriate technologies that mitigate environmental impacts including those from small-scale mining operations.
8. Seek to provide additional funds and innovative financial arrangements to improve environmental performance of existing mining operations.
9. Adopt risk analysis and risk management in the development of regulation and in the design, operation, and decommissioning of mining activities, including the handling and disposal of hazardous mining and other wastes.
10. Reinforce the infrastructure, information systems service, training and skills in environmental management in relation to mining activities.
11. Avoid the use of such environmental regulations that act as unnecessary barriers to trade and investment.
12. Recognise the linkages between ecology, socio-cultural conditions and human health and safety, the local community and the natural environment. (Revised)
13. Evaluate and adopt, wherever appropriate, economic and administrative instruments such as tax incentive policies to encourage the reduction of pollutant emissions and the introduction of innovative technology.
14. Explore the feasibility of reciprocal agreements to reduce trans-boundary pollution.
15. Encourage long term mining investment by having clear environmental standards with stable and predictable environmental criteria and procedures.

6 THE BOOKLETS ON BEST PRACTICE ENVIRONMENTAL MANAGEMENT IN MINING

Mining, exploration and energy extraction are carried out in many different geographic regions in Australia, including the surrounding seas and oceans. Differences in climate, topography, soils, flora, fauna and land use, mining techniques and commodities being extracted lead to differences in the possible impacts of exploration and mining and the environmental management and rehabilitation techniques required to minimise and repair these impacts.

The booklets provide personnel responsible for environmental issues, irrespective of the mine's location, with the information they need to achieve good environmental performance, minimise conflicts with other land users, maintain ecological values in surrounding areas and restore or enhance the land use capability of the areas affected by their activities. They cover planning, monitoring, management systems and technical issues. The information is also valuable for staff at other levels and in other areas of the mining company hierarchy to improve their understanding of environmental issues and to build a sense of responsibility amongst all mine staff. Members of stakeholder representative groups, regulatory authorities, and students of mining and environment subjects will also find the booklets a valuable resource to improve environmental awareness, understanding of various principles and technologies, and the capacities of leading practitioners to significantly reduce the level of environmental impact from mining.

All the booklets include illustrated case studies which demonstrate the application of a wide range of best practice techniques to address different environmental issues across many different mine type, commodity, geographic and environmental settings. The booklets offer references for further information and some contain short guides on the steps to be taken to achieve best practice on the specialised topic.

A checklist is also available for each booklet topic. The checklists are aimed at assisting small to medium scale mining enterprises with limited access to environmental expertise to identify the steps to be taken in order to conform to best practice behaviour. The checklists may also be used as prompts for designing simple audit protocols for each specialised topic, which can be used by internal and external auditors, and by regulators.

The following brief descriptions for each of the booklets available at July 2002 summarise the topics covered, the contents of each booklet, and key recommendations.

6.1 MINE PLANNING FOR ENVIRONMENT PROTECTION (VIEW BOOKLET)

Planning is the key to identifying and minimising the environmental impacts of mining. This booklet examines one crucial part of the process – how mine planning for environmental protection can help in developing projects that meet community expectations for minimal environmental impacts. It outlines the considerations that

shape mining methods and the design of environmental safeguards. These considerations include: air, water and noise quality; vibration; transport; biological resources; social and economic factors; visual impacts; surrounding land uses; and heritage places and artefacts.

Each mineral deposit is unique and so planning needs to take into account the detailed nature of the resource to be mined. The nature and sensitivity of the surrounding environment must be understood through baseline monitoring and data collection in order to provide environmental constraints for mine planning. Community expectations must be garnered through constructive dialogue with the community and representative bodies. A sound information base will allow appropriate and sensitive options to be developed, which will include the rate and direction of mining, alternative process designs, optimal facility layout, and the location of supporting services and infrastructure. It is critical that the mine is built as planned and approved during the government assessment process, staff are trained to provide adequate skills to properly implement the plan, and that environmental monitoring and auditing are undertaken throughout mine life to check on the adequacy of performance and to implement improvements where necessary.

6.2 ENVIRONMENTAL IMPACT ASSESSMENT (VIEW BOOKLET)

This booklet describes the background to and purposes of environmental impact assessment (EIA). It briefly covers the legislative requirements within Australia and the key components of EIA. The relationship between EIA and environmental management plans, monitoring, and environmental management systems are discussed.

EIA is a central part of the project approval process for mining in Australia, and has evolved since the 1970s to become a comprehensive and detailed integral part of project development and design. EIA is the best way of predicting potential impacts and identifying early on in the planning process effective and efficient ways of mitigating them. EIA also provides a sound basis upon which to devise special regulatory requirements, design appropriate Environmental Management Systems, plan the environmental monitoring regime, and identify focal issues for environmental auditing and reporting.

An EIA should contain an introduction to the project's proponents; the location, environment and a background to the project and its objectives; a comprehensive and detailed description of the environment before development commences, including the physical, biological and social aspects which the project is most likely to effect; a detailed description of the project at each stage of development and operation (ie. site preparation, construction, operation, proposed expansions, decommissioning, rehabilitation and site closure); identification of issues relating to possible physical, ecological, land use, social, infrastructure, heritage or other issues; a description of how the identified impacts will be managed and the levels of protection to be provided; an evaluation of alternative approaches to development (eg lower mining rate, milling infrastructure remote from mine, different waste disposal options, local or remote housing of mine staff); consideration of the "no development" option to enable appreciation of the consequences of the project not going ahead; a description of the proposed assessment, monitoring and review

procedures; and a list of the commitments made by the proponents to minimise the environmental impacts of the proposal.

6.3 COMMUNITY CONSULTATION AND INVOLVEMENT (VIEW BOOKLET)

The expectations and needs of communities affected by mining proposals are considered in this booklet. The processes for preparing for the consultation process are discussed in detail and the key community consultation techniques described. A community-centred, rather than a project-centred approach to community consultation and involvement is preferred.

There are no shortcuts to developing effective community consultation programs. Gaining local support involves convincing all the community's sub-groups that their interests will not be overlooked or prejudiced. It helps to: start consultation very early; clearly demonstrate the integration of social, economic and environmental aspects of the project; emphasise tangible benefits to the local community (eg jobs, skills training) and make sure these happen; be always visible and accessible to openly discuss issues; be aware of changing concerns and interests in the community over time and address these directly through direct consultation; and maintain a flexible approach to consultation and ongoing modification to project design over the life of the mine.

6.4 ENVIRONMENTAL MANAGEMENT SYSTEMS (VIEW BOOKLET)

This booklet outlines the role and key components of an environmental management system (EMS) as a key tool to use in achieving the company's environmental objectives and targets. It explains how to operate and implement an EMS within a company's daily operations, from exploration to mine closure. An EMS is a structured approach to managing the environmental aspects of a project so that nothing is overlooked; tasks are done and checked; provision is made for changes, and response procedures established for emergencies. It avoids a haphazard process of site-based, narrowly focussed and non-integrated responses to individual environmental challenges. EMS is a major contributor to demonstrating due diligence.

The components of a comprehensive EMS for a mine site include: organisational commitment; corporate environmental policy; EIA; community consultation and involvement; objectives and targets; environmental management program; documentation and records; operational and emergency procedures; responsibility and reporting structure; training, awareness and competence; audit systems for environmental impact, regulatory compliance and environmental performance; and emission and performance monitoring and measurement.

6.5 ENVIRONMENTAL RISK MANAGEMENT (VIEW BOOKLET)

Environmental impact is unavoidable in mining – decisions are constantly being made, with action or inaction, which affect the likelihood of negative impacts from foreseen or unforeseen events on the mine site or from the effects of external forces. Assessing these changes should include risk management. Environmental Risk

Management (ERM) is defined and the key principles described. ERM methods and practice are discussed, including scoping of the risk analysis to be undertaken; the elements of risk analysis and the differences between quantitative and qualitative approaches; assessment of risk; and the different methods of risk treatment or management. Different forms of EMS are described as they are appropriately applied in the different stages of mine life. For example in the pre-mining stage, careful and considerate mine planning and concept development, and thorough environmental impact assessment, are very influential and effective tools in reducing risk and the potential for major financial outlays through the remainder of the mine's life (eg by avoiding or minimising exposure to costs of modifying systems, rectifying impacts or paying fines).

Key points made in this booklet are that some level of risk is unavoidable, but it can be significantly reduced if an integrated approach to ERM is taken. ERM helps to ensure that environmental risk is contained to acceptable levels, and ideally it should be applied to all aspects of a mining operation in a structured process to ensure that all relevant issues are addressed. Criteria and objectives for risk assessment should be established early on and an open mind maintained in respect of the assumptions that are always made because of limited knowledge – information and experience gained during operations, such as the results of environmental monitoring, should be fed into the risk assessment process to identify emerging problems as soon as possible and progressively reduce risk levels with time. As ERM encompasses the entire mine project, multiple skills are needed and sufficient resources must be made available to do the job effectively. The results of the risk analysis must be communicated effectively and risk management recommendations implemented promptly for the ERM process to succeed.

6.6 CLEANER PRODUCTION (VIEW BOOKLET)

Cleaner production is a concept that encompasses many of the operational practicalities of best environmental practice on a mine site. It is aimed at maximising resource usage and operational efficiency, not only during production of the mineral commodity at the mine, but also in its fabrication, use and ultimate disposal (eg as copper wiring and tubing in a refrigerator). The concept also extends to minimising waste disposal and rehabilitation requirements, and its application is linked to continuous improvement in environmental and economic performance.

This booklet describes how cleaner production requires a change in attitudes, acceptance of responsibility for environmental management, and ongoing evaluation and, where appropriate, upgrading of technological options. Cleaner production looks to identify, remediate, minimise or remove an environmental problem before it happens; it looks for "beginning of pipe solutions" instead of allowing the problem to continue and addressing it by applying an "end of pipe" solution. In other words, it is an integrated and *preventative* approach to minimising environmental risk, rather than a *curative* approach. It involves good housekeeping throughout the mine site, and ongoing procedures to identify opportunities for further improvement. The benefits of cleaner production can include less waste, recovery of valuable by-products, improved environmental performance, increased resource productivity, better efficiency, reduced energy consumption and an overall reduction in costs.

6.7 PLANNING A WORKFORCE ENVIRONMENTAL AWARENESS TRAINING PROGRAM (VIEW BOOKLET)

A workforce environmental awareness training program is important in achieving an enduring and improving environmental culture amongst all staff. The booklet explains how corporate commitment is critical to a successful program. It also provides a framework that managers can use in planning a workforce environmental awareness training program and shows how its effectiveness can be evaluated. Key components of building a culture of environmental awareness and concern in the workplace are good communication with all staff; encouragement and motivation for workers to change their views on and levels of commitment to environmental protection; strong, clear and continued leadership; encouraging team approaches to address environmental issues; clear understanding of the issues to be addressed and building of sufficient skills amongst staff to ensure that staff have the knowledge and competencies to take appropriate measures when needed; appropriate recognition to staff and teams for good work; and empowerment through delegation to allow workers to become responsible directly for their own actions. Such measures lead to higher morale, lower staff turnover, employees taking more responsibility and displaying initiatives in environmental protection, and overall improved environmental performance.

6.8 ONSHORE MINERALS AND PETROLEUM EXPLORATION (VIEW BOOKLET)

This booklet discusses the potential environmental impacts that can arise at the different stages of exploration, and management of those impacts. Impacts can be minimised through participation of stakeholders, personnel training, and selection, use and timing of appropriate equipment. Best practice in exploration starts with pre-exploration planning and continues until exploration is completed. Any exploration program should ensure proper communication to stakeholders about the program of work and its outcomes; protection of the environment outside the exploration area; minimisation of disturbance and contamination within the explored area; and restoration of all impacted areas at the end of the program. Effective and practical techniques to minimise impacts and restore the area at the end of exploration are discussed in the booklet.

6.9 WATER MANAGEMENT (VIEW BOOKLET)

Water is integral to virtually all mining activities and typically the prime medium, besides air, that can carry pollutants into the wider environment. Consequently, sound water management is fundamental for most mining operations to achieve environmental best practice. As mine planning is commonly based on limited data it is important to validate initial predictions as soon as possible in the operational phase and adjust the water management system to minimise the risk of environmental impact. A mine's water management system (WMS) must account for site-specific physical, chemical and climatic characteristics as well as mine process factors. As water features in most operational aspects, total company commitment to integrated water management is critical. Periodic risk/consequence assessments will check WMS effectiveness and allow changes to reduce the risk of system failures and environmental impacts, and also help to "fine tune" rehabilitation planning to achieve desirable post-mining land use objectives.

The booklet describes the hydrological cycle; the physical and process elements of a WMS; outlines how a best practice water management plan can be devised and developed; and examines the different water management issues which pertain at different stages during the life of a mine.

6.10 TAILINGS CONTAINMENT (VIEW BOOKLET)

All aspects of planning, designing, constructing, operating and monitoring tailings disposal facilities are covered in this booklet. Factors to consider in selecting the site and choosing between the various disposal options for tailings are explained, and monitoring and control methods to minimise environmental impacts are discussed.

Tailings storages can cause a number of short and long term environmental problems if not well designed, constructed and managed. The problems relate to contamination of surface and ground waters, dam safety and stability, dust, visual impact, reclamation and restoration of the area, and long term maintenance, stewardship and mitigation of contamination.

The booklet describes the objectives for tailings storage; site suitability; different tailings containment designs; and operating and monitoring approaches and techniques.

6.11 ENERGY EFFICIENCY (VIEW BOOKLET)

Energy is critical for all mining activities to continue their operations. Energy is a major operating cost and usually requires substantial capital investment. Energy generation and consumption are also known to be a significant contributors to greenhouse gas emissions; and performance in this area is seen as a key indicator of the environmental credentials of industries in general and individual companies. Voluntary and mandatory targets are being set by many jurisdictions and the move to tax greenhouse gas emissions in many countries adds extra incentive to improve performance and efficiency.

Solar lighting saves energy related costs and as they don't require site wiring, installation costs
Photo courtesy Australian Greenhouse Office

The booklet explores opportunities to directly reduce costs through reduction in energy consumption and improvements in efficiency, and to reduce emissions related to energy use. Management approaches are examined for providing leadership through building awareness, measuring energy use, identifying opportunity for improvement, and reporting outcomes. Methods of increasing the efficiency of energy use are applicable across all activities in the minerals sector and are discussed for exploration, excavation, ventilation and dust extraction, water management, transport, crushing milling and processing, and general site services. Particular attention is given to the sources of greenhouse gas emissions and how these can be reduced, including the application of alternative products and processes.

6.12 ATMOSPHERIC (NON DUST) EMISSIONS (VIEW BOOKLET)

Most of the techniques involved in ore processing are sources of non-dust emissions to the atmosphere, such as radioactive gases and particles from uranium ore and mineral sands processing; odorous gases during ore concentration employing sodium ethylu xanthate; acid gases from roasting of sulphide ores; and hydrogen sulphide and other acid gases when bricks are heated in kilns or aluminium is reduced.

The booklet discusses what clean air is, describes the common pollutants, and summarises the Australian regulatory controls and standards. Different control techniques are described for capturing pollution and treating pollutants using adsorption, absorption, incineration, and sulphuric acid plants. Atmospheric dispersion of pollutants is also discussed, including the influences of terrain, meteorology, buildings, and convection, and the effectiveness of stacks to reduce impacts. Modelling and assessment of odour are briefly described.

Key elements of best practice in managing atmospheric pollution are to use technology which reduces generation of gaseous emissions and which eliminates gaseous waste streams through recycling. Emissions should be treated to reduce them as far as practicable. All pollutants must be identified and appropriate technologies selected to control them effectively. Care must be taken in designing stacks to suit local meteorological, topographic and built environment conditions, and to take account of gas cleaning technologies that reduce the temperature of emissions inside the stack. Fugitive emissions should be captured by hooding systems. Odour monitoring is important to provide fast warning of emissions problems, as dispersion models may not provide information quickly enough to allow speedy response to emission levels which may give rise to health concerns or complaints from workers and the community.

6.13 DUST CONTROL (VIEW BOOKLET)

Dust is unavoidable for almost all forms of mining – it is one of the most visible, invasive and potentially irritating impacts and commonly causes more concern than is warranted from neighbouring communities. However, many dusts do contain potentially hazardous metals and certain types and size ranges of dust are known to have associated health impacts. It can also affect flora and fauna and poses a health risk to mine workers. Dust control must therefore be part of a mine environmental management plan.

The booklet describes the origin of dust in mining, the characteristics of dust from different operations, and the health risks it poses. As dust transport and deposition on sensitive recipients are influenced by many operational, climatic and topographic variables, the importance, type and application of dust modelling and prediction are described. Methods to control dust can be incorporated at the mine planning stage. Knowledge must be acquired during the operational phase to understand how dust is generated and how it can be most effectively controlled. An understanding of dust emission sources and use of on-line monitoring technology can be used to provide real-time dust data for input to active dust management through adjustments to mine operations and dust suppression such as watering and sealing of surfaces, or delay of blasting under adverse weather conditions.

6.14 NOISE, VIBRATION AND AIRBLAST CONTROL (VIEW BOOKLET)

Noise, vibration and airblast are unavoidable in many types of mining and constitute significant threats to worker health and safety if not well managed. Noise and vibration require particular management at projects close to communities, where they can give rise to concerns for public health, safety, and damage to private and public buildings and other infrastructure. The mine planning stage should recognise the potential for adverse impacts, and layout, infrastructure and systems designed to mitigate possible impacts. The extent of noise, vibration and airblast should be quantified during the environmental impact assessment stage and predictions made of the levels likely at potentially sensitive locations, such as the nearest dwellings, school or public place. A management plan should be prepared in consultation with the local community, including specific measures to minimise emission levels. Ongoing monitoring during construction and operation will provide information for assessment of performance against objectives, and data for effective auditing throughout the life of the mine.

The booklet looks at the sources of noise, vibration and airblast, describes why they are of concern and need to be understood and managed; characterises what they comprise; gives examples of the effects they can cause; and sets out a three-stage approach to their management (impact assessment, management plan, monitoring and auditing).

6.15 HAZARDOUS MATERIALS MANAGEMENT, STORAGE AND DISPOSAL (VIEW BOOKLET)

Hazardous materials include any substance that may pose a hazard to human health or the environment when improperly treated, stored or disposed of. Most mining and mineral processing facilities use and generate hazardous materials. Approaches to minimising risk from these substances include: identifying and properly preparing materials, and compiling inventories of all hazardous materials including waste products; characterising the potential environmental hazards associated with them; documenting methods for transport, storage, handling and use; identifying options for disposal and long term storage, preparing contingency plans and emergency response plans; and training of all managers, workers and contractors who deal with or handle hazardous substances.

The booklet defines hazardous materials and describes why they must be properly managed. It also lists many of the materials and wastes associated with mining,

under the categories of exploration activities, process chemicals, service materials, process wastes, radioactive materials, and other waste streams. Principles of best practice materials management are set out, and the need is stressed for comprehensive management plans and systems for all stages and areas where hazardous substances are involved. Finally, suggestions are made for review and auditing of systems for the management of hazardous materials.

6.16 CYANIDE MANAGEMENT (VIEW BOOKLET)

The economic viability of many gold mines is dependent upon the efficiency of cyanide as a solvent. However, cyanide use brings with it the risk of health impacts to workers, the public and the environment if cyanide chemistry, handling, containment and disposal are not properly understood and practiced. This booklet includes a chemical overview of cyanide during gold extraction, recycling and disposal, and describes how health and environmental risk can be minimised. As cyanide exists in many different forms and may undergo many different transformations, an understanding of the chemistry is important in developing best practice approaches to its management. Management principles include: using the minimum amount required to recover metals; disposal techniques which eliminate the potential for impacts; and monitoring of all operations, discharges and the environment to detect and deal with any escape of cyanide and any resultant impacts.

Integrated management of cyanide should include: a cyanide management plan, which must be integrated with the water management plan; training for all staff and contractors; clear documentation of responsibilities and authority, and defined lines of communication in respect of cyanide management; development and promulgation of safe procedures for cyanide handling including transport, storage, containment, use and disposal; identification and implementation of appropriate methods for reusing, recycling and disposal of residual cyanide; regular cyanide audits and revision of the cyanide management plan where appropriate; a cyanide occupational and natural environment monitoring program and sampling, analysis and reporting protocol; and cyanide emergency procedures and emergency practice sessions.

Best practice cyanide management will lead to benefits such as better relationships with the public and regulatory agencies, improved economic and environmental performance, reduced risks and liabilities, and easier access to capital and potentially lower insurance costs.

	Term	Analytical type [a]	Species or compound	log equilibrium constant [b] and solubility data	Toxicity to fish [c] (LC_{50} in mg/L)
1.	Free cyanide	free cyanide	CN^- HCN	not applicable 9.2	~ 0.1 0.05 to 0.18
2.	Simple compounds a) readily soluble	free cyanide	KCN(s)* $NaCN.2H_2O$(s) $Ca(CN)_2$(s)	sol = 71.6g/100g H_2O (25°C) sol = 34.2g/100g H_2O (15°C)	0.02 to 0.08 0.4 to 0.7 –
	b) relatively insoluble	WAD/CATC/total	CuCN(s) $Zn(CN)_2$(s) $Ni(CN)_2$(s)	–19.5 –15.9 sol = 9.1 x 10^{-4}g/100g H_2O (25°C)	– – –
3.	Weak complexes	WAD/CATC/total	$Cd(CN)_4^{2-}$ $Zn(CN)_4^{2-}$	17.9 19.6	– 0.18
4.	Moderately strong complexes	WAD/CATC/total	$Ni(CN)_4^{2-}$ $Cu(CN)_2^-$ $Cu(CN)_3^{2-}$ $Cu(CN)_4^{3-}$ $Ag(CN)_2^-$	30.2 16.3 21.6 23.1 20.5	0.42 – 0.71 (24 hours) – –
5.	Strong complexes	total	$Fe(CN)_6^{4-}$ $Fe(CN)_6^{3-}$ $Au(CN)_2^-$	35.4 43.6 38.3	35.0 (light); 860 to 940 (dark) 35.2 (light); 860 to 1210 (dark) –
	Thiocyanate		SCN^-	not relevant	50–200
	Cyanate		CNO^-	not relevant	34–54

(a) WAD = weak acid dissociable; CATC = cyanide amenable to chloride; total = total cyanide following acid distillation (see Section 2.1).
(b) Measure of stability, given only for comparative purposes; values quoted in the literature are quite variable.
(c) Toxicity data is given only for guidance and should be used for comparative purposes only, a dash indicates 'no relevant data found'.
(Beck, 1987; Hagelstein, 1997; Minerals Council of Australia,1996; Richardson, 1992)
* (s) = solid

Nomenclature, stability and toxicity of some important cyanide species in gold mining tailings. The booklets contain technical information relevant to each topic such as chemical characteristics, nomenclature, equations, flowcharts, standards and regulatory requirements. This is one of many tables in the Cyanide Management booklet that sets out information critical to understanding why and how best practice techniques must be applied.

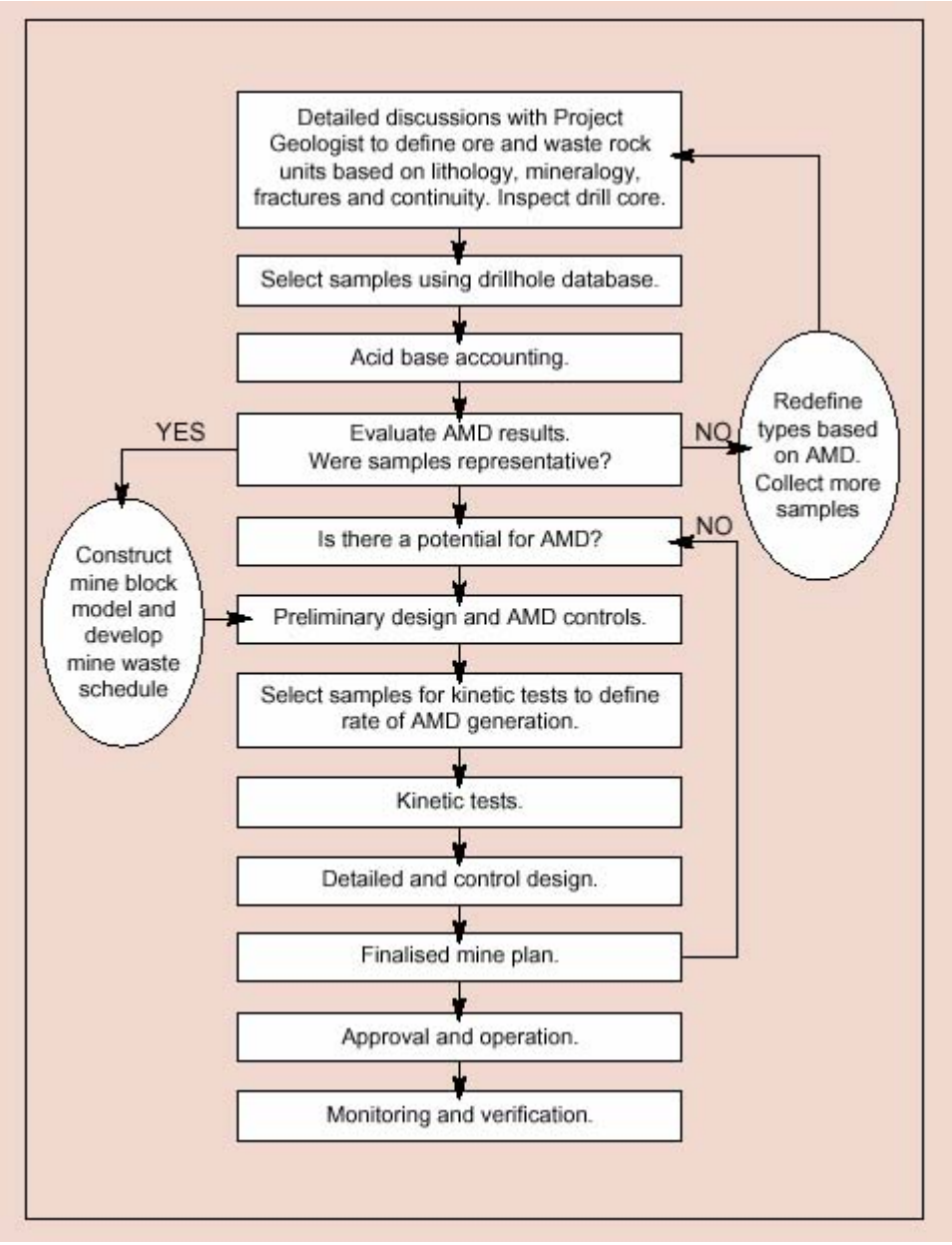
6.17 MANAGING SULPHIDIC MINE WASTES AND ACID DRAINAGE (VIEW BOOKLET)

Excavation and breaking of rock containing sulphidic minerals will accelerate the production of acid drainage, which at mines typically occurs as runoff or seepages from waste rock piles, tailings impoundments, coal reject piles, mine dewatering, or from flooded pits or underground workings. The financial impacts of acid drainage are considerable: the cost of remediating acid-generating materials in Canada is estimated at around $C 3 billion, and the annual management cost to the mining industry in Australia is about $A 60 million (Harries 1997).

Best practice environmental management must directly address the potential risks and effects of acid drainage by: characterising mine waste for its acid-producing potential; using site-specific analysis to determine the levels of environmental risk; implementing mine design and mine management practices to avoid or minimise the risks; designing monitoring programs which will provide early identification of any impact on the environmental values at risk; mine planning and closure strategies which minimise the potential for off-site impacts; and ensuring the long term effectiveness of the acid drainage management strategies developed for the site.

The booklet illustrates the importance of control of acid drainage by describing several mine sites where major environmental damage has resulted from

uncontrolled or poorly controlled acid drainage. Techniques are described for predicting and identifying the potential for acid drainage. Different approaches are described for reducing the generation of acid from sulphidic materials, ie by reducing oxygen and water access, isolation, blending and by bacterial inhibition. Different strategies are described to treat acid waters by neutralisation, and with passive constructed and natural (ie wetlands) systems. Concepts and some techniques for monitoring are briefly outlined.



The booklets contain guidance in the form of flow charts for managers and practitioners such as this step-by-step guide to evaluating acid mine drainage potential from the Managing Sulphidic Mine Wastes and Acid Drainage booklet.

6.18 ENVIRONMENTAL MONITORING AND PERFORMANCE (VIEW BOOKLET)

This booklet looks at the objectives of monitoring programs for air, water, dust, flora and fauna and community impact, including the selection of indicators, measurement methods, data collection and analysis, and reporting of monitoring

data. The linkages between environmental monitoring and performance, and environmental auditing and EIS predictions are explained.

The environmental monitoring program collects and interprets the information necessary to determine whether the environmental management plan and related systems are being applied effectively, and whether the environmental objectives set by the company, regulator and community are being properly met. The booklet describes the principles for design of a monitoring program, and how these can be implemented for different monitoring targets such as water, land, biota, air, noise, processing systems, waste, and people and the community. Methods for data collection, evaluation and presentation are also discussed, and comments made on the cost of implementation. Clearly a quality monitoring program is critical to inform the company, the regulatory authorities and the community on the level of environmental protection being achieved. Proper interpretation will provide the information necessary to enable early changes to the mining operation if unacceptable impacts are indicated or predicted, and will form the basis of credible technical reporting. occurring.

6.19 ENVIRONMENTAL AUDITING (VIEW BOOKLET)

Environmental auditing is an essential management tool to measure overall performance objectively and to develop action plans for ongoing improvement in the effectiveness and efficiency of environmental protection. An audit program will help demonstrate due diligence in the event of confrontations with stakeholders, or prosecution. Environmental audits must not be one-off events but should be repeated at regular intervals to provide periodic assessments of the effectiveness of environmental management systems. Whilst internal auditors can undertake them, independent audits are usually needed for the results to be credible to regulators and stakeholders. The benefits of environmental auditing include identification and management of risk; lower probability of non-compliance; preferred access to lending institutions; lower insurance premiums for environmental risk; and improved public image.

Environmental audit is a voluntary activity in Australia but it is commonly demanded by stakeholder groups, and by codes of practice or standards adopted by many operators. It is common for regulators to undertake inspections in the form of environmental audits, and in some instances these may be undertaken jointly with stakeholder groups to improve transfer of information and mutual trust.

There are many different types of environmental audit that reflect the level of sophistication of a company's environmental management plan and systems; and the purpose and objectives for the audit. Internal or external auditors may conduct audits. The type of audit depends on the focus of the audit exercise, which may be compliance against regulations, legislation, and licences; or environmental outcomes; or a specific technical part of the overall operation; or related to assessing a company's financial, insurance, or product liabilities. The different audit types are explained and examples given. Guidance is provided on how to select auditors, choose the right type of audit, develop protocols, prepare for the audit, and conduct the on-site audit procedures. The importance is stressed of communicating the results of the audit and of implementing audit recommendations effectively and promptly. An effective cycle of audit planning, execution and implementation of recommendations is a major contributor to the key sustainable development principle of continuous improvement.

6.20 CONTAMINATED SITES (VIEW BOOKLET)

Contamination is an ever-present risk in mining because of the materials involved – mineralised rock, tailings, process chemicals, lubricants, fuels and other solid and liquid materials are all potential contaminants. Best practice starts with minimising the potential for contamination of land by designing systems to reduce the potential for releases to the environment including waste minimisation and management strategies and operating procedures. The management of contaminated land needs to be an integral part of the environmental management system and auditing procedures.

The booklet recommends a risk-based approach rather than one based on concentration levels, as this allows for the use of innovative and cost-effective strategies to manage contaminated land. While overall mine and mine systems design should minimise the potential for contamination and provide adequate safeguards in the event of failure, it is also important that mine staff are able to react quickly, appropriately and confidently to deal with any contamination event. Assessment of contamination prevention and control measures in regular environmental audits will allow improvements to be made to effectively manage the likelihood of and impacts from contamination over the life of the mine and through its various stages of operation and management.

The booklet describes why contamination at mines is a problem, discusses the issue of liability, and summarises current regulatory requirements placed on Australian mines. The different mining processes which can lead to contamination are described, at the exploration and trial mining stage; during construction; during the operational phase through processing/extraction, tailings storage, handling of waste chemicals, consumables and equipment; and in the context of management procedures and human behaviour. Approaches to reducing the risk of contamination in all of these settings is discussed in terms of technological, operational and management solutions. The nature of mining means that it is very difficult to avoid some level of contamination from occurring, and so the booklet also discusses various approaches to assessing contamination and how contaminated land can be remediated. Heavy contamination may place restrictions on future use of the area, which may have serious consequences for discharge of liabilities at mine closure.

6.21 LANDFORM DESIGN FOR REHABILITATION (VIEW BOOKLET)

Best practice demands that mining is a temporary user of land and that the land should be returned to some beneficial use for the community after mine closure. Landform design is critical to achieving this objective. Traditional mining activity either left the land with no shaping, or left any shaping until the end when the size of the problem and low cash flows generally resulted in a minimalist program of landscaping works. This approach also often meant that the best options for placement of contaminated or other hazardous materials such as rock with acid-forming potential to reduce long-term risk were no longer available.

This booklet demonstrates how mine planning can integrate ongoing landform reshaping works throughout the operational phase at minimal cost so that the prospects of achieving desirable post-mining land use objectives to the satisfaction of regulators and the community are maximised. This booklet should be read in

tandem with the *Rehabilitation and Revegetation* booklet to determine how climate, soil, local topography, management requirements and the like are best factored in to the landform design.

The value of the land, its proximity to larger communities, and its natural attributes (such as slope, rainfall, fertility), and the type of mine, will dictate sensible and achievable post-mining land use options and thus the most appropriate objectives for landform design. The booklet includes an example of how different outcomes are warranted for a coal mine in a relatively well populated area with a viable pastoral cattle industry, in contrast to a low grade and high-throughput gold mine in a remote and arid environment where there is little commercial land use.

Planning aspects for landform design are discussed, and design parameters described to produce a landform compatible with the surrounding natural landscape (ie hydrology, drainage channel types and density, slopes, and relationship between landform and land use). Survey methods, land use options and design considerations are discussed for in-pit spoil and waste rock, and for other materials, including the use of computer-assisted planning and design tools. In many circumstances it may be economically impractical to fill in voids, and so alternatives to use of voids in the post-mining landscape are discussed and their safety aspects considered. Water control is an important post-mining management issue, and techniques are described for water control, and minimising erosion.

6.22 REHABILITATION AND REVEGETATION (VIEW BOOKLET)

Rehabilitation is an essential part of achieving ecologically sustainable development in mining. It cannot be considered only towards the end of mine life; to be effective it must be part of an integrated management plan right from the mine planning stage, and must incorporate research and trials to improve the probability of success and acceptance by regulators and the community.

Rehabilitation can take different forms – for example in mining areas close to towns where a range of land use options such as playing fields, industrial development, housing, water recreation and parkland is potentially appropriate. In more remote areas, restoration into natural rangelands may be the only option. In many parts of remote Australia, agriculture is commonly marginally viable because of low rainfall and fragile and low-fertility soils and the levels of soil or pasture improvement are very low. Therefore mine rehabilitation commonly takes a form of ecosystem restoration. Mining organisations and research institutions have developed expertise to re-establish floral and faunal species that will develop into communities with similar biodiversity to undisturbed systems.

The booklet emphasises the rehabilitation of natural ecosystems, particularly the re-establishment of native flora. Topics covered include rehabilitation objectives; land clearing, soil handling, storage and replacement; landform design and erosion control earthworks; species selection, seed collection and treatment, and application techniques; the use of fertilizers and soil amendments; nutrient building and cycling; maintenance; and monitoring and measuring revegetation and rehabilitation success.

6.23 MINE DECOMMISSIONING (VIEW BOOKLET)

Mine decommissioning and closure is the process of shutting down an operation so that the area is left in a safe and stable condition, which is consistent with the surrounding environment, and does not need ongoing maintenance.

Decommissioning determines what is left behind as a benefit or legacy for future generations. If decommissioning and closure are not undertaken in a planned and effective manner, the site may continue to be hazardous and a source of pollution for many years to come. The overall objective of mine closure is to prevent or minimise adverse long-term environmental impacts, and to create the agreed beneficial land use objectives.

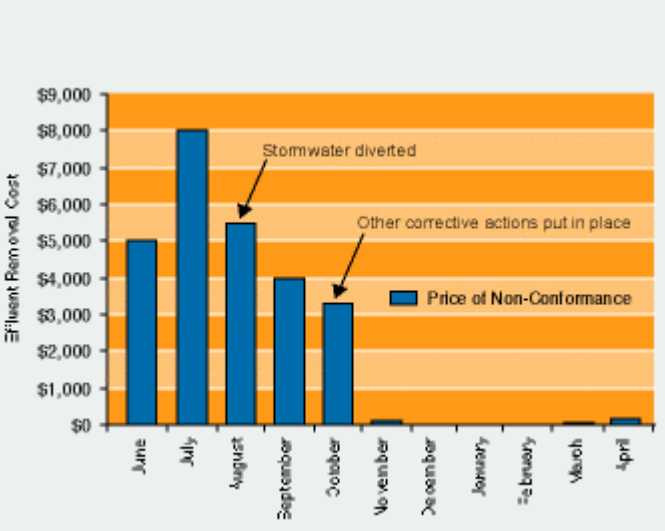
There are no standard formulae that can be applied, as each operation and its situation is unique. Appropriate mine decommissioning outcomes need to be determined on a site-specific basis taking into account climate, land capability, land form, water resources, ongoing land use and the risks associated with alternatives. Factors important in considering decommissioning options include: public safety hazards and risks; ecological compatibility; potential for ongoing pollution; community expectations; future land use and resource demands; and aesthetics.

The benefits from best practice mine decommissioning include: reduction of liabilities; sufficient financial and material resources set aside for final closure requirements; rehabilitation designs and/or processes tested for their suitability for the specific site; less double-handling of waste materials and topsoil; less land disturbed; identification of areas of high risk as priorities for ongoing research and/or remediation; realistic estimation of rehabilitation costs; potential to progressively recover performance bonds; and reduced impacts on local communities that may be economically reliant on mine operations.

7 WHAT DOES BEST PRACTICE COST?

Best practice environmental management in mining can increase financial outlays for mining operations in the short term. These costs must be accounted for in any mining operation. Outlays directly associated with integrating environmental management into all aspects of mining (such as environmental impacts assessment, community consultation and involvement, mine planning for environmental protection, monitoring) are estimated by the industry to be up to 5% of both capital and operating costs for new mining projects. This figure will vary according to such factors as physical differences in sites and methods of mining (eg open pit or underground).

However, these costs can generally be offset against the many financial benefits that best practice brings. These can include direct and immediate cost savings by avoiding unacceptable environmental impacts caused by mining operations. Longer term gains include decreasing future costs for decommissioning, and improving acceptability of a successful operator's future mining proposals. Whilst it is not easy to put figures against these benefits, it is easy to see that the up-front cost of best practice environmental management in mining reaps long term gains for the mining industry, the community and the environment.



Ongoing costs to remove effluent were effectively reduced to zero after a range of measures were implemented to avoid water contamination at Orica's testing facility for mine explosives in Melbourne (from Cleaner Production booklet).

To ignore environmental factors at the start of a mining project and then be forced to retrofit, redesign and rebuild, or change practice later, is not only poor engineering and planning, but it is also often very expensive – for example, consider the cost of importing topsoil to rehabilitate a mine site because the original topsoil was removed or buried. It is clearly cheaper and more efficient to integrate environmental factors from the beginning than to clean up a site at the end of mine life when cash flow has ceased and materials and equipment may have to be mobilised from off-site.

As well as reducing future liabilities for site cleanup, a company that employs best environmental practice can reap immediate gains through reducing outlays in security deposits. For example, the Queensland Government calculates security deposits required of a mining project against environmental performance criteria.

The best performers pay 25% of the estimated decommissioning liability costs for a mining project, while other companies have to pay up to 100% of the estimated costs as a security to the government. Some jurisdictions also operate inspection and audit regimes in which the impositions on operators decrease where there is evidence of better management systems and a consistent track record of environmental protection.

It is more relevant to rephrase the question at the beginning of this chapter as "What is the cost of not pursuing best practice?" Many best practice principles are embedded in the Australian Minerals Industry Code for Environmental Management. All Australian jurisdictions specify elements of best practice such as environmental impact assessment, community consultation, environmental monitoring regimes, specific environmental protection objectives, forward-looking mine plans, and tailored environmental management systems; and recommend others such as adherence to international standards for environmental management, regular independent auditing, pursuit of targets for energy efficiency, and adopting of the principles of continual improvement, cleaner production and the precautionary approach. Best practice approaches are now widely accepted as the necessary norm by governments and stakeholders, and increasingly by other sectors such as the financial, insurance, and consumer goods fabrication industries. Poor environmental performance is likely to bring with it more difficult access to project funding, complex and lengthy impact assessment procedures with lower certainty of outcome, greater chance of regulatory non-compliance, and poor relationships with staff, non-government organisations and the surrounding community.

8 CONCLUSION

The continued development of the mining and energy industries in accordance with the principles of ecologically sustainable development is important for the maintenance of Australia's environment and economy.

There are now many excellent examples in Australia where the development of mineral or energy resources has been carried out while maintaining environmental values and ecosystems. The booklets in this series outline the expertise that produces best practice environmental management behaviour and outcomes in Australia's mining and energy sector. By applying the information within these booklets to their own particular situations, mining managers with environmental responsibilities should be able to implement environmental management approaches that meet all the environmental protection objectives developed by the company, in conjunction with regulators and stakeholders.

Development and application of best practice environmental management are not just the responsibility of the industry. Government plays a critical role in providing legislative and regulatory frameworks that encourage – or demand – best practice. Best practice, as a minimum, must be grounded on a set of clearly defined, rigorous and monitorable environmental principles and standards with which industry must comply, and it is the role of government to set those standards and monitor performance against them. Self–regulation and beyond–compliance initiatives by industry will in themselves not guarantee best practice environmental protection if the regulatory base is weak.

Best practice implies continual improvement to maintain maximum performance. The booklets are designed to encourage continual environmental improvements towards best practice and benchmarking within the mining industry to achieve an acceptable level of environmental protection. In so doing, the mining industry will be integrating economic, environmental and social considerations into its operations in a practical way.

The booklets are also designed to be accessible to a wider audience other than mine environmental managers, including other mine workers, members of stakeholder groups, and students of mining and the environment. They are also relevant to industry sectors other than mining where similar environmental problems may arise, as many of the planning, management, operational, monitoring and reporting principles and techniques are applicable across a wide range of industry settings.

The booklets can contribute to understanding and achieving best practice by improving the level of understanding of all parties on the issues involved, and by describing the principles and practices that can be employed to improve environmental outcomes. Improved understanding by all parties, willingness to exchange information, and responding to the concerns of the other parties, will provide a sound basis for the further development of mining as an environmentally responsible industry.

REFERENCES AND FURTHER READING

"What happened in Bonn? – The Nuts and Bolts of an Historic Agreement" – International Energy Agency.

National Greenhouse Gas Inventory (NGGI) – 1995 cross-sectorial analysis.

Australian Greenhouse Challenge Office (AGO) information.

Minerals Industry Greenhouse Workbook – Australian Greenhouse Office, Minerals Council of Australia and Australian Coal Association.

WEBSITES AND FURTHER READING ON GENERAL MINING AND ENVIRONMENTAL ISSUES, POLICIES, PROGRAMS AND TECHNIQUES

Best Practice Environmental Management in Mining – booklets, training kits, environmental management tools and resources – http://www.ea.gov.au/industry/sustainable/mining/

Environment Australia – http://www.ea.gov.au/

Australian Greenhouse Office (AGO) – http://www.greenhouse.gov.au/

AGO Funding Programs – http://www.greenhouse.gov.au/ago/funding/index.html

Office of the Renewable Energy Regulator – http://www.orer.gov.au/

Minerals Council of Australia – www.minerals.org.au/

Australasian Institute of Mining and Metallurgy – www.ausimm.com.au/

Australian Mineral Foundation – http://www.amf.com.au/

Australian Petroleum Production and Exploration Association – http://www.appea.com.au/

Australian Centre for Mine site Environmental Research – http://www.acmer.com.au/

CADDET (International Energy Efficiency Database) – http://caddet-ee.org/

Cooperative Research Centre for Mining Technology and Equipment – www.cmte.org.au/

Energy Efficiency Best Practice Website – http://www.isr.gov.au/resources/netenergy/domestic/bpp/index.html

Department of Industry, Tourism and Resources – http://www.industry.gov.au/

Sustainable Energy Development Agency – www.seda.nsw.gov.au

Sustainable Energy Industry Association – www.seia.com.au

Julius Kruttschnitt Mineral Research Centre – www.jkmrc.uq.edu.au

McIntosh Engineering Ltd (USA) – Rules of Thumb for the Mining Industry http://www.mcintoshengineering.com/Hard%20Rock%20Handbook/rulesofthumb.htm#view

Mining and Management Article – http://www.wspc.com.sg/profiles/anncat/anncat/jnlarticle/mrev9n2/S0950609800000184.pdf

Motor Solutions Online – http://www.industry.gov.au/motors/

General information on Australia's policies, strategies and actions on ESD – http://www.ea.gov.au/esd/index.html

Information on programs and initiatives by Australia's Federal Government for sustainability in industry - http://www.ea.gov.au/industry/index.html

Links to publications and Australian government web pages on ESD - http://www.ea.gov.au/esd/publications/index.html

Information on environmental management techniques has been published by government departments and industry associations. Some useful references are:

- Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland, 1995. Department of Minerals and Energy. Brisbane, Queensland. ISBN 0724252606;
- Guidelines for Mining in Arid Environments, 1996. Department of Minerals and Energy, Perth, Western Australia. ISBN 0730978028;
- Mine Rehabilitation – a Handbook for the Coal Mining Industry, 1995. New South Wales Minerals Council, Sydney NSW. ISBN 0949337625; and
- Environmental Management in the Australian Minerals and Energy Industries, Principles and Practices. Mulligan DR (editor) 1996. University of New South Wales Press/Australian Minerals and Environment Foundation. Sydney NSW. ISBN 0868403830.

International resources for BPEM are accessible through the internet pages of the United Nations Environment Programme (UNEP) – http://www.mineralresourcesforum.org/tutorial.htm

Major international initiatives to promote sustainability in mining are being pursued through:

- The Global Mining Initiative – http://www.globalmining.com/index.asp ; and
- The Mining, Minerals and Sustainable Development Project - http://www.iied.org/mmsd/

The Australian report prepared for the MMSD Project is available at - http://www.ameef.com.au/mmsd/pdfs/report/ozreport.pdf

WEBSITES ON AUSTRALIAN ENVIRONMENTAL AWARD SCHEMES

Banksia Awards - www.banksiafdn.com/awardabout.html

Northern Territory Government - http://www.dme.nt.gov.au/dmemain/awards/2001/Awards_categories.htm#environ mgt

New South Wales Government - http://www.minerals.nsw.gov.au/minfacts/11.htm

Tasmanian Government - http://www.dpiwe.tas.gov.au/env/env_awards/awards2001.html

Western Australian Government - www.dme.wa.gov.au/goldengecko/about.html

SPONSORS

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