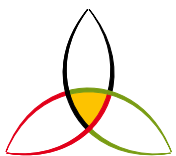




Australian Government
Department of Resources
Energy and Tourism

RISK ASSESSMENT AND MANAGEMENT

LEADING PRACTICE SUSTAINABLE
DEVELOPMENT PROGRAM FOR
THE MINING INDUSTRY



SOCIAL
ECONOMIC
ENVIRONMENTAL

RISK ASSESSMENT AND MANAGEMENT



MAY 2008

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

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

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

A wide range of organisations have been represented on the Steering Committee and Working Groups, indicative of the diversity of interest in mining industry leading practice. These organisations include the Department of Resources, Energy and Tourism, the Department of the Environment, Water, Heritage and the Arts, the Department of Primary Industries (Victoria), the Department of Primary Industries (New South Wales), the Minerals Council of Australia, the Australian Centre for Minerals Extension and Research and representatives from mining companies, the technical research sector, mining, environmental and social consultants, and non-government organisations. These groups worked together to collect and present information on a variety of topics that illustrate and explain leading practice sustainable development in Australia’s mining industry. The resulting handbooks are designed to assist all sectors of the mining industry to reduce the negative impacts of minerals production on the community and the environment by following the principles of leading practice sustainable development.

A handwritten signature in black ink, appearing to read 'M Ferguson'.

The Hon Martin Ferguson AM MP
Minister for Resources and Energy, Minister for Tourism



1.0 INTRODUCTION

1.1 Leading Practice Sustainable Development Program

The Leading Practice Sustainable Development Program aims to identify the key issues affecting sustainable development in the mining industry and provide information and case studies to illustrate a more sustainable basis for the mining industry. The leading practice handbooks are relevant to all stages of a mine's life—exploration, feasibility, design, construction, operation, closure and rehabilitation.

1.2 Audience

The primary audience for this handbook is onsite mine management—the pivotal level for implementing leading practice at mining operations. It is the responsibility of the mine manager to assess risk, identify opportunities and take action to enhance the value of the operation.

The handbook is also relevant to people with an interest in leading practice in the mining industry, including environmental officers, mining consultants, governments and regulators, non-government organisations, mine communities and students. All readers are encouraged to continually improve the mining industry's performance in the area of risk assessment and management by applying the principles outlined in this handbook.

1.3 Risk assessment and management context

This handbook addresses the issue of risk assessment and management in the Australian mining industry. In the mining industry—with its inherent potential for major accidents which could injure or kill people, damage the environment, cause serious loss of production and therefore profit—there is a particular need for a sound approach to the process of risk management.

Risk assessment and risk management is inherently about the management of unplanned events. Unplanned events which occur on a mine site, or within the surrounding environment or community, have the potential to impact on the viability of a mine or community. The process of assessing and managing these risks is aimed at reducing the likelihood that these negative events will occur and increasing the likelihood that positive outcomes will be realised.

1.4 Scope

In applying risk management across the minerals industry, well-credentialed risk management frameworks need to be applied for all aspects of the life cycle, including mining, processing and downstream stewardship of minerals and metals products. Such an approach provides, wherever possible, a transparent risk management approach more likely to have the wide support of stakeholders.

In Australia and New Zealand a generic framework exists for establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk—this framework is the AS/NZS 4360:2004 Risk Management Standard. This handbook does not attempt to rewrite the standard but, instead, applies the standard to the context of the mining industry in a practical way. The handbook discusses the importance of sustainable development and its relationship to the mining industry in terms of environmental, social and economic risks. It outlines the most common risks that affect the industry and presents examples of the key risk management frameworks used to assess and manage these risks. The key chapters of the handbook outline the process of analysing, identifying and evaluating risk, and discuss how these risks can be controlled through proper planning and decision making. Finally, the handbook emphasises the importance of communication, both internally and externally, throughout the risk assessment and management process.

1.5 Business case

The business case for effective risk management is well understood within the Australian minerals industry, although there are varying degrees of emphasis placed on the risk types that organisations focus on. This is a result of the corporate memory of what risks the organisation and industry sector have had to deal with in the past, and the experience of senior managers and the decision makers within the business to foresee risks to the business in the future.

Effective risk management ensures that:

- the health, safety and wellbeing of employees and the public is not compromised;
- financial performance of the business is protected;
- a business earns its social licence to operate in the eyes of local communities, regulators and other stakeholders, based on performance; and
- the reputation of a business is strengthened.

If these outcomes are consistently met, the business is likely to prosper, contributing to a more sustainable industry.



2.0 SUSTAINABLE DEVELOPMENT AND RISK MANAGEMENT

Purpose

This section defines sustainable development and risk concepts and presents the business case for embracing a robust and comprehensive risk management approach within the minerals industry.

KEY MESSAGES

- The challenge of sustainable development requires the minerals industry to adopt proactive risk management approaches that recognise, integrate and implement the three pillars of social, environmental and economic sustainability.
 - Risk is defined as the combination of the probability (or likelihood) and consequence of an event (or outcome or result of exposure). This gives rise to the widely used concept of risk: Risk = Probability x Consequence.
 - Risk management for mining needs to recognise uncertainty and unpredictability, fill key information gaps to reduce uncertainty, and work with key stakeholders in the practical implementation of the Precautionary Principle.
-

2.1 Introduction

Risk management is a core element of sustainable development. The three pillars of sustainability—social, economic and environmental—present various risks and thereby provide a complex and often inter-related mix of risks and opportunities that mining companies need to address.

To provide a formal and consistent framework for sustainable development in the Australian mining industry, the Minerals Council of Australia has developed *Enduring Value—The Australian Minerals Industry Framework for Sustainable Development*. The *Enduring Value* framework is intended to facilitate mining companies to go beyond statutory compliance and contribute positively to sustainable development.

Enduring Value Principle 4

Implement risk management strategies based on valid data and sound science.

- Consult with interested and affected parties in the identification, assessment and management of all significant social, health, safety, environmental and economic impacts associated with our activities.
- Ensure regular review and updating of risk management systems.
- Inform potentially affected parties of significant risks from mining, minerals and metals operations and of the measures that will be taken to manage the potential risks effectively.
- Develop, maintain and test effective emergency response procedures in collaboration with potentially affected parties.

This section presents an overview of the minerals industry response to sustainable development and how risk management is applied to corporate policy and mine operations throughout mine life cycles. When risk management principles are applied proactively, business performance is enhanced, reputation is strengthened and social licence to operate is maintained.

2.2 Risk: Key definitions and concepts

The formal Australian Standard for Risk Management, AS/NZS 4360:2004, provides a generic guide for managing risks and is the common starting reference for all forms and areas of risk management.

Risk is defined as “the chance of something happening that will have an impact on objectives” (AS/NZS Risk Management Standard, p. 3), meaning risk can be either positive or negative. Risk management is therefore defined as “the culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects” (AS/NZS Risk Management Standard, p. 4). In the context of the sustainability challenge, the mining industry therefore has to manage numerous risks throughout the mine life cycle by reducing risks to acceptable levels while pursuing business objectives and opportunities.

A common approach is to define risk as the combination of the probability (or likelihood) and consequence of an event (or outcome or result of exposure). This gives rise to the widely used concept of risk:

$$\text{Risk} = \text{Probability} \times \text{Consequence}$$

Risk management is not a singular process but a complex mix of multiple views, values, perceptions and qualitative or quantitative approaches. This means that sound risk management must involve components of stakeholder engagement, two-way communication and responsiveness.

This handbook presents a variety of concepts, aspects and frameworks for understanding and managing risks associated with the minerals industry, and their relationship to sustainable development.

2.3 Risk and sustainable development

The challenge of sustainable development presents a variety of risks (and opportunities) for the minerals industry. These need to be considered in light of social, environmental and economic risks to all stakeholders affected by mining—local communities, investors and shareholders, governments, Indigenous groups, mining companies and so on. These pillars of sustainability are pivotal in understanding risks and the inter-relationships between them.

The published handbooks in the *Leading Practice Sustainable Development in Mining* series cover specific aspects of mining, such as tailings management, biodiversity management, managing acid and metalliferous drainage, mine rehabilitation, stewardship, community engagement and development, working with indigenous communities, mine closure and completion, water management and cyanide management. Future handbooks will also cover hazardous materials management, particulate, noise and blast management and monitoring, auditing and performance. These handbooks address key risk areas often faced by the minerals industry. In a booklet like this it is impossible to cover every risk that might be relevant to the sustainability of the minerals industry, but a representative selection has been included.

The nature of mining can often present a range of uncertainties—on the extent of environmental impacts, social benefits, economic outcomes, geologic conditions and even political risks. Stakeholders will have different perceptions of uncertainty and the various aspects of mining. As noted in *Enduring Value*, implementing sustainable development principles requires mining professionals to consider the complexity of stakeholder relationships that may exist over the long term and at great distances.

The Precautionary Principle

The 1992 Rio Declaration on Environment and Development provides the following definition:

"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Although the precautionary principle was originally framed in the context of preventing environmental harm, it is now widely accepted as applying broadly where there is threat of harm to human, animal or plant health, as well as in situations where there is a threat of environmental damage.

However, the definition is only a starting point. Policy guidelines are needed to indicate when, for example, the Precautionary Principle should be invoked, how a risk-based approach can continue to be followed when the scientific uncertainty is such that conventional risk assessment cannot in itself determine the level of risk, and how decisions should be made on appropriate precautionary measures.

The purpose of the Precautionary Principle is to create an impetus to take a decision notwithstanding scientific uncertainty about the nature and extent of the risk; that is, to avoid 'paralysis by analysis' by removing excuses for inaction on the grounds of scientific uncertainty.

The Precautionary Principle should be applied when, on the basis of the best scientific advice available in the time-frame for decision making:

- there is good reason to believe that harmful effects may occur to human, animal or plant health, or to the environment
- the level of scientific uncertainty about the consequences or likelihoods is such that risk cannot be assessed with sufficient confidence to inform decision-making.

Source: United Kingdom Interdepartmental Liaison Group on Risk Assessment (UK-ILGRA); www.hse.gov.uk/aboutus/meetings/ilgra/pppa.htm#3

Uncertainty arises due to the complex inter-relationships between economic, environmental and social risks. This situation is illustrated in the case study: Risk Management of the Ok Tedi Project, Papua New Guinea.

CASE STUDY: Risk management of the Ok Tedi project, Papua New Guinea

Key messages

- When risk management is not undertaken thoroughly, it can lead to major flow-on impacts on an individual mine, company and the mining industry.
- Sustainability requires that the complex relationships between various risks be well understood, especially the potential for links between environmental, social, political, economic and reputation risks.

Background

The Ok Tedi copper-gold project is a memorable name in the mining industry. The deposit was discovered in the 1960s and subsequently developed by an international consortium led by BHP Ltd in the mid-1980s. The project is located in the Star Mountains of Western Papua New Guinea (PNG). The remote region has intense rainfall, steep and rugged mountains, is prone to landslides and is also within a seismically active area. The engineering challenges for mine waste and environmental management in this context are significant.

Risks

Significant risk was at the forefront of the debate about Ok Tedi from its inception—major environmental risks, social risks (especially with respect to the indigenous communities in the region) and economic risks that are commonly associated with a developing country existed, including government and governance risks (for example, Pintz 1984).

Risk and consequence

Construction of a tailings dam was started but abandoned in 1984 due to a major landslide which effectively destroyed the dam. Subsequently, Ok Tedi was given approval for the tailings from the mine to be discharged into the neighbouring Fly River.

In 1994, the villagers downstream from the Ok Tedi mine took legal action against BHP Ltd, claiming extensive environmental and social impacts as a result of the tailings discharge into the river. This court case was settled in 1996, with the company making compensation payments and commitments to study future mine waste management options. The case not only caused major damage to BHP's corporate reputation, but also to the reputation of the mining industry globally.

In 2002 BHP ceased its involvement in the project, transferring majority control of Ok Tedi to the new PNG Sustainable Development Program Ltd.



The Ok Tedi mine. Image Source: Ok Tedi Mine CMCA Review

Risk management

There are many risks which need to be considered with a project such as Ok Tedi. The extent and nature of environmental impacts present numerous and varied risks—during operation as well as during closure, and following rehabilitation. The social risks are difficult to assess—who receives benefits versus negative impacts, and are further complicated by the varying perceptions of the nature of social risks (within PNG and externally in the developed world). Initially the economic impacts and risks of the project may appear to be easy to ascertain and assess but the costs and externalities derived from environmental and social impacts can be very significant and impact on project economics.

Operating major mining projects presents an array of governance and government risks. For example, when governments are minority investors in projects (the receivers of royalties and taxes) as well as regulators, the perceived conflict of interest and need for transparency presents major challenges.

The Ok Tedi project and the dilemmas it raises are not unique in the world—the multi-faceted and interconnected nature of risk is at the heart of the sustainability debate. The mining industry can contribute to sustainable development by striving to understand the complex relationships between social, environmental, economic and governance risks.

The Ok Tedi case has helped to lift the awareness of these issues in the mining industry as well as the public realm along with the need to implement sound risk management for such large and complex projects and improve the global mining industry's approach to risks and sustainability.

References

Pintz, WS 1984, *Ok Tedi—Evolution of a Third World Mining Project*, Mining Journal Books, London, UK, p. 206.

To manage risk effectively, uncertainty and unpredictability must be recognised and, where possible, key information gaps need to be filled to reduce uncertainty. This also requires engagement with relevant stakeholders to understand their point of view. Some of the areas of unpredictability faced by the mining industry relate to exploration success and new discoveries, the success of closure strategies and mine rehabilitation, climate effects and economic conditions; in particular, the cost of energy, commodity prices and exchange rates.

Risk management processes within the minerals industry often focus on the incremental risks from the operation of a single facility. Where a single mine operation is remotely located, this approach may be legitimate. However, where mining and mineral processing activities occur in clusters, in conjunction with other industries or in proximity to sensitive receptors, cumulative impacts may need to be considered. In these situations, the role of government is important. A broader-based approach is required to develop policy and regulatory instruments to protect human health and the environment. Such an approach must take into account multiple sources, pathways and routes of exposure. This holistic approach may require more complex analyses involving cumulative risk assessment. In such cases, the Precautionary Principle may need to be applied if significant levels of uncertainty remain.

Cumulative risk can be due to aggregate effects of multiple mining operations in a region or the combination of different impacts from a single mine (such as noise, air, water and visual amenity issues). Cumulative risk is likely to be less obvious—often subtle and spread over time. For health and environmental risks, science continues to provide improved monitoring and evaluation methods. Many communities take cumulative risks very seriously and, in the modern information age, it is critical to realise that if cumulative risks are not well acknowledged and managed this can significantly impact on a company or sector's social licence to operate.

The environmental and economic risks of mining are generally well identified and managed, but social risks remain a more challenging area for the minerals industry. Social risk can manifest in a variety of ways—through Indigenous issues, community development, workforce issues and so on. The relationships between social, environmental and economic risks are often not clearly defined or easy to clarify—yet they must be incorporated into risk management to ensure the minerals industry contributes strongly to sustainable development.

CASE STUDY: Argyle Diamond mine, Western Australia

In December 2005, Rio Tinto approved a major investment to extend the Argyle Diamond mine into an underground block cave operation. The existing open pit was scheduled to close in 2010, while the extension would allow the operation to continue until 2025. As would be expected for an investment of this size, the feasibility study included a comprehensive risk assessment covering all aspects of the proposal. These included not only the financial and technical risks associated with the change to a new mining method, but also the environmental and social implications.



Argyle Diamonds' mine. Image source: Rio Tinto

The team charged with assessing these sustainable development implications focused, in particular, on the impacts of the decision on two communities. The first was the mainly Indigenous regional population of the East Kimberley area where the mine is located. In recent years Argyle Diamonds had adopted a strong localisation focus, moving away from a fly-in, fly-out model and increasing its Indigenous employment target to 40 per cent. The second focus was on the large number of people involved in processing Argyle's

diamonds downstream in India—an estimated 220 000 workers. In this decision there was no ‘do nothing’ option, but each alternative involved its own particular set of risks and opportunities.

Team-based workshops were used to address the social risks and opportunities for the two community areas. The workshops were preceded by detailed commissioned research into the social and economic context of the two communities in question, and the potential impacts of the two scenarios. The workshops involved both internal and external participants and, wherever possible, used the same risk assessment protocols as the more technical areas. This allowed the outcomes to be readily integrated into the overall risk register for the project. New controls were developed for key areas and the residual risks recalculated. The social risks were among the highest rating group for the whole project. The workshops served to identify areas where proactive management could increase positive outcomes associated with the decision scenarios.

As the industry integrates sustainable development considerations into its decision making processes, the treatment of external socio-economic risks and opportunities will become increasingly important. The ‘mainstreaming’ of these issues into risk management processes reflects their significance and importance to most large mining and processing operations.

Mining project risks need to be considered over long timeframes. Many assumptions are made in relation to the long-term risk profile of a mining operation. During project development phases (feasibility and design), mine closure and rehabilitation objectives need to be defined. This process will require input from regulatory authorities and local community stakeholders. Assurance mechanisms will normally be required by regulators to ensure that funds are available to deal with situations where closure and mine site rehabilitation objectives are not met (Australian Government, 2006b, 2006c).

Given the long-term implications of decisions made at the project development phase, it is vital that risk assessment workshops are held at key stages—usually at pre-feasibility, feasibility and project execution stages. The outcomes of these risk workshops must drive decisions on the future direction of the project.

A critical component of all risk management processes is risk communication. This issue is covered later in the handbook. As noted, different stakeholders understand and perceive risks in various ways, and react accordingly. Communication of risk must be a two-way process, proactive at all the life cycle stages of a mine, and consistent and responsive to feedback. During risk communication, listening is often more critical than presenting.

2.4 Research and development

The Australian minerals industry endeavours to adopt a proactive research and development (R&D) approach to filling key information gaps related to risks for its operations and products. Drivers behind these efforts are the industry's public commitment to sustainable development and the ongoing development of new regulatory regimes.

R&D engagements by the industry are purposely made with authoritative, independent, third party research providers. These engagements, by their very nature, set the scene for wide stakeholder confidence in research outcomes.

Studies undertaken may relate to risk issues at the company, industry and commodity levels. At the company level, issues such as emissions to the environment, contaminated sites and the toxicity characterisation of process wastes and products are investigated. The information from these studies is often used in regulatory assessments of risks, for example, the use of smelter wastes in the cement industry.

At the industry or commodity level, research may encompass more generic studies often related to protective guidelines for air, water and soils. An example of such work is the recently completed program by CSIRO aimed at the development of scientifically robust guidelines for copper in sediments. This work was jointly supported by Rio Tinto, BHP Billiton and Xstrata Copper. Also, in the international context, CSIRO and the Chinese Academies of Science and Agricultural Science are developing appropriate copper and nickel guidelines for Chinese soils with support from Rio Tinto, the International Copper Association and the Nickel Producers Environmental Research Association.

In summary, the challenge of sustainable development requires the minerals industry to adopt pro-active risk management approaches that recognise, integrate and implement the three pillars of social, environmental and economic sustainability.



3.0 TYPES OF BUSINESS RISK

Purpose

This section presents the various types of risks faced by mining and mineral processing operations and provides an example of an enterprise-wide risk framework.

KEY MESSAGES

- Strategic risks are those which affect business survival or the long-term sustainability of an operation. Businesses respond by acting on opportunity or managing potential threats. Operational risks affect mining and mineral processing operations more directly and over shorter timeframes, and are usually the focus of site management.
- Mining and mineral processing operations face many types of risks including workplace health and safety, environmental, public health and safety, regulatory, production, reputation and financial risk.
- An enterprise-wide risk framework provides guidance for a systematic, rigorous, integrated, and consistent risk management process to be implemented organisation-wide, so that material risks can be identified, communicated and acted on at appropriate levels within an organisation.

3.1 Introduction

Risks are identified, analysed, evaluated and managed across a variety of business boundaries and activities. For mining and mineral processing operations, agreement on how to recognise the various types of risks they face and the management practices to address these risks is vital for the sustainability of their activities, whether they are large projects or small, established operations and process plants or development opportunities.

Risks present in two ways: strategic and operational.

Strategic risks are those which affect business survival, strategic goals or the long-term sustainability of an operation. Strategic risks also relate to the interdependencies between an operation's activities and the broader business environment. For example the continued availability of water on site is a strategic risk to the business and has a broad range of impacts on mine operations. Restricted water supply impacts on the production capacity of a

mine or mineral processing operation. Development of new water supplies can have broader environmental, social and cost implications that must be considered in feasibility studies and decision making.

Climate change and the potential impact of carbon trading schemes or taxes is another example of a strategic risk for an operation with significant greenhouse gas emissions.

Operational risks affect more systematic aspects of a process or operation. They are those risks that can be readily identified as having one or more types of impact and which affect an expected outcome. A number of risk impact types are discussed below. Different operations and their activity areas will face any number of operational risks. These types of risks (in terms of a threat or opportunity) are an integral and unavoidable component of business. Proactive management of operational risks requires the application of rigorous and systematic risk processes for all areas of the business including business planning, internal projects and investments, and the maintenance of safe and secure operations.

Risk terminology normally implies the possibility of a negative impact and the need to identify and manage threats or hazards. However, risk assessment methodology can be expanded to identify and evaluate positive opportunities. By identifying and evaluating opportunities (or positive risks), management activities to control the opportunity can be assigned in the same way a potential threat (or negative risks) would be controlled or mitigated.

Both strategic and operational risks need to be recorded and communicated to appropriate levels throughout the organisation so that decision makers can effectively allocate resources. The risk register is the tool most often used to collate risk information. Once established, a risk register should be reviewed and updated on a regular basis. The risk register can be used by management to check that strategic and operational plans are appropriately addressing the key risks to the business.

Risk registers can be very simple documents, highlighting key risks and priorities. A register may also include risk assessment outcomes in terms of consequence, likelihood and risk ratings, action plans and an assessment of residual risk once planned controls have been implemented.

3.2 Types of business risk

3.2.1 Workplace health and safety

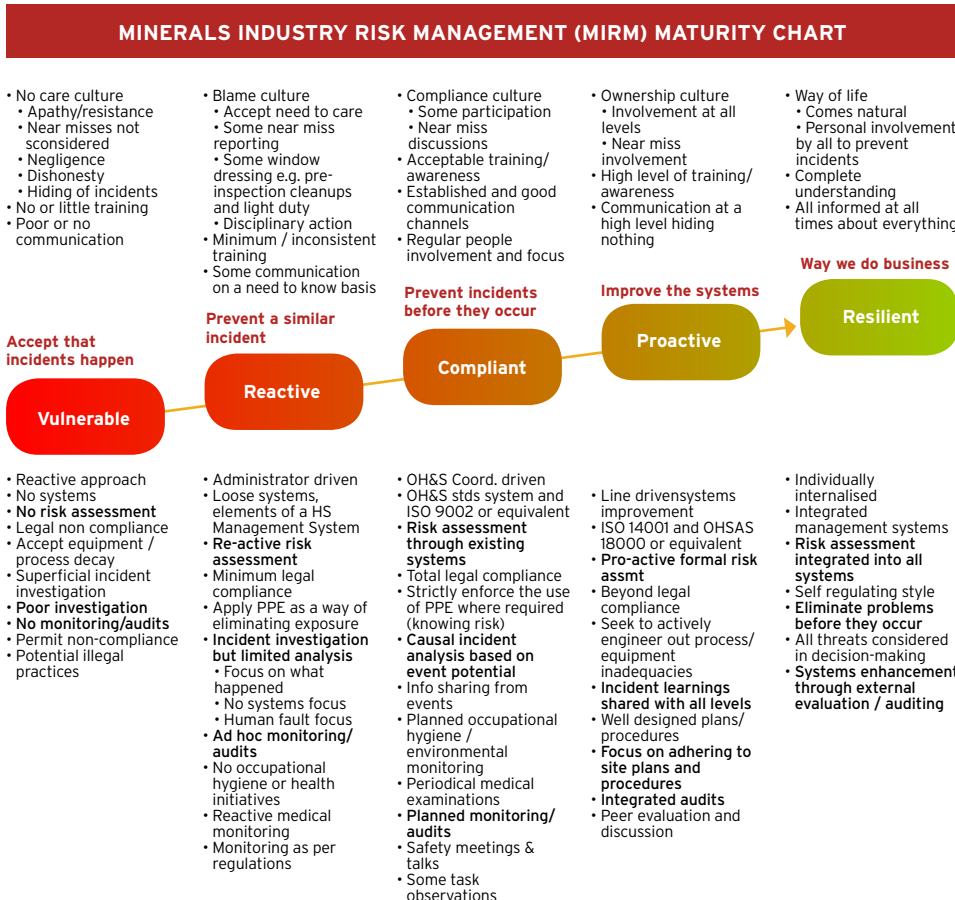
These risks are those which present a risk to the health or safety of people. Safety risks are characterised by acute consequences, ranging from first aid, lost time injury, to permanent disability or single and multiple fatalities. Health risks are those which affect people's health through chronic exposure leading to illness.

Health and safety risks receive significant management attention within the minerals industry. This is due to the nature of the activities and the working environment in which the business operates and the range of hazards that must be managed. The consequences of an unsafe workplace are unacceptable to employees, their families, communities, government health authorities and mining companies. There are strong social and business drivers to improve the health and safety of employees. Poor health and safety performance seriously damages the reputation of an organisation and the industry as a whole.

A number of guidelines have been prepared to assist the Australian minerals industry implement standardised and robust risk management processes to protect the health and safety of people. The *National Minerals Industry Safety and Health Risk Assessment Guideline* (Minerals Industry Safety and Health Centre 2005) outlines various risk assessment approaches ranging from informal risk assessment and Standard Operating Procedures (SOPs), through to formal safety assessments and catastrophic risk management plans. The guideline provides a robust, process-based methodology to risk assessment that will assist in making a step change in risk assessment within the minerals industry.

Another publication, *Minerals Industry Safety and Health Risk Management Guideline*, is designed to assist minerals industry sites with the development of an effective risk management system (NSW Department of Primary Industries 1997). The guideline covers the relevant terminology and a number of risk management approaches. Since every site is different, the guideline provides an easy-to-use approach to achieving a resilient, integrated risk management system. The 'journey' to this goal is based on the Minerals Industry Risk Management (MIRM) Maturity Chart, a version of the Hudson Ladder (Hudson 2001), illustrating that the development of effective risk management systems involves several step changes. The MIRM Maturity Chart provides a clear link between improvement in the culture of the organisation and the development of a systems approach.

Figure 1: Minerals Industry Risk Management (MIRM) Maturity Chart, based on the Hudson Ladder and a similar approach used by Bayside Aluminium, a BHP Billiton site in Richards Bay, South Africa. Source: NSW Department of Primary Industries, 1997.



The *Minerals Industry Safety and Health Risk Management Guideline* outlines the following risk assessment techniques (see the MISHRMG for more details and more methods including templates at www.mishc.uq.edu.au):

- **Informal risk assessment (IRA)**—general identification and communication of hazards and risks in a task by applying a way of thinking, often with no documentation.
- **Job safety/hazard analysis (JSA/JHA)**—general identification of hazards and controls in a specific task, usually for development of a standard work practice (SWP).
- **Energy barrier analysis (EBA)**—detailed analysis of determining phases of events and control mechanisms.
- **Preliminary hazard analysis/hazard analysis/workplace risk assessment and control (PHA/HAZAN/WRAC)**—general identification of priority risk issues/events, using qualitative or semi-qualitative risk analysis methods, often to help determine the need for further detailed study.

- **Hazard and operability study (HAZOP)**—systematic identification of hazards in process design.
- **Fault tree analysis (FTA)**—detailed analysis of contributors to a major unwanted event, potentially using quantitative risk analysis methods.
- **Failure modes, effects and criticality analysis (FMECA)**—general to detailed analysis of component reliability risks (Department of Primary Industries 1997).

3.2.2 Risk and the natural environment

Environmental risk may be defined in two ways. Firstly, and more commonly, environmental risk can be defined in terms of the impact of exploration, mining or mineral processing activities on the environment. Secondly, environmental risk can be thought of in terms of environmental factors or 'Acts of God' which may present a risk to the sustainability of the operation. For example, a major rainfall event flooding a mine or causing overtopping of process water, or the converse—a long dry period during which water supply cannot meet demand.

Environmental risks from an operation's activities and their potential impact on the environment and local community may have a range of impacts on the business, such as community health impacts, public outrage leading to reputation damage, cost of closure and rehabilitation, and ongoing legacy risks after closure.

Opportunities may also arise from risks to the natural environment. For example, in an area where artisanal and small-scale mining is being practiced by a community, the business may share its knowledge and tools with those artisanal miners to reduce their impact on the community and natural environment.

CASE STUDY: Mt Lyell Copper mine impacts in Macquarie Harbour, Tasmania

The 100-year operation of the Mount Lyell Mining and Railway Company Ltd copper mine in Queenstown, Tasmania, resulted in more than 100 million cubic metres of mine tailings, smelter slag and topsoil being deposited into the King River and Macquarie Harbour. Despite the cessation of tailings dumping, exposed tailings on the river banks and in the delta continually leach iron, manganese, aluminium and copper, which have contributed substantially to the metal loads in Macquarie Harbour waters and sediments.

In the mid-1990s, the Mount Lyell Remediation Research and Demonstration Program, undertaken jointly by the Supervising Scientist and the then Tasmanian Department of Environment and Land Management, aimed to assess the environmental risk of metal release from the mining operation and to develop a remediation strategy.



Mt Lyell Copper mine geographical location. Image Source: Google Maps

A preliminary risk assessment of copper in Macquarie Harbour waters compared monitoring data for copper in mid-salinity waters with literature data on copper toxicity for a wide range of estuarine species. This showed that there was a probability greater than 0.98 that dissolved copper concentrations in the harbour would exceed the copper concentration (with 50 per cent confidence) harmful to at least five per cent of species. Dissolved copper concentrations as high as 500 $\mu\text{g/L}$ had been reported in harbour surface waters near the mouth of the King River, although typical concentrations ranged from 10 $\mu\text{g/L}$ to 100 $\mu\text{g/L}$ of copper. Electrochemical techniques showed that a significant proportion of the dissolved copper was in a chemical form that was potentially available for uptake into aquatic organisms. Fish, benthic invertebrate communities and phytoplankton were found to have lower abundance and/or species diversity than in other south-eastern Australian estuaries.

A comprehensive study was then undertaken to assess the environmental impact of metal release from the mine and smelter as part of the development of a remediation strategy. The chemical forms (speciation of copper) and their potential availability to estuarine organisms in Macquarie Harbour waters were investigated using the approach now outlined in the ANZECC/ARMCANZ (2000) water quality guidelines. This included studies on the chemical speciation of copper and direct toxicity assessment (DTA) using microalgae, crustaceans and juvenile flounder.

Using electrochemical and resin techniques, DTA revealed that there were no significant effects on algal growth, crustacean and flounder survival, or osmo-regulation or copper accumulation in flounder. This result was in contract with results from chemical speciation techniques which showed that copper in the harbour waters was potentially bioavailable. Further tests showed that these waters were not toxic to the microalga *Nitzschia closterium*, despite the fact that they contained copper concentrations greater than that known to cause inhibitory effects on this alga (Stauber et al. 2000).

Amelioration of copper toxicity was probably due to binding of dissolved organic matter at the algal cell surface, preventing copper binding and uptake into the algae.

This case study demonstrates the inadequacy of relying on one single line of evidence in risk assessment. Screening level assessments based on chemical analyses and literature data alone may overestimate or underestimate risk. To better evaluate risk and develop appropriate remediation options, site-specific investigations—including chemical speciation analyses, direct toxicity assessment and biological monitoring as outlined in the current ANZECC/ARMCANZ (2000) guidelines—are often required, together with an understanding of mechanisms of toxicity.



The King River. Image Source: Jenny Stauber, CSIRO

References

ANZECC/ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council and Agricultural & Resource Management Council of Australia and New Zealand, Canberra.

Stauber, JL, Benning, RJ, Hales, LT, Eriksen RS & Novak, B 2000, 'Copper bioavailability and amelioration of toxicity in Macquarie Harbour, Tasmania, Australia', *Marine and Freshwater Research*, vol. 51, pp. 1-10.

CASE STUDY: Supporting responsible small-scale gold mining, AngloGold Ashanti, Africa

Communities near AngloGold Ashanti's operations in Ghana, Guinea, Mali and Tanzania depend on the income from small-scale artisanal mining, but working conditions are often unsafe and mercury used to extract the gold can pollute local water supplies.

Governments find it difficult to regulate artisanal mining and are turning to large companies for help. AngloGold Ashanti is promoting alternative business and job opportunities for local people in its own operations, and encouraging responsible artisanal mining nearby.

In 2005, a workshop at AngloGold Ashanti's mine in Geita, Tanzania, attracted 95 artisanal miners. The miners wanted to learn about safer mining techniques and the loans that were available to start-up small businesses. This led to AngloGold Ashanti hosting a trade fair for artisanal miners. Several non-governmental organisations and other large mining companies participated. Information was provided on micro-finance, loans and bank accounts, training in safe and responsible mining, and alternative job opportunities in the area.

The company is exploring the possibility of allowing artisanal miners to work areas of its land where there is insufficient gold to justify commercial mining, but which could be successfully exploited on a smaller scale. This would help to legitimise artisanal mining, promote communications with local communities and reduce disturbance to the company's operations.

AngloGold Ashanti plans to help reduce mercury pollution from artisanal mining by offering miners cleaner technologies in partnership with the United Nations Industrial Development Organisation Global Mercury Project.



Artisanal Mining in Tanzania. Image Source: AngloGold Ashanti

The Australian Government has prepared an *Environmental Risk Assessment Guidance Manual for Industrial Chemicals* (Australian Government, in draft, 2007d). This manual outlines how the assessor should carry out an assessment of a new or existing industrial chemical according to best practice, including what information, methods and tools to use in assessing chemicals. This information is provided as guidance rather than prescriptive methodology as each assessment needs to be tailored to fit the particular chemical being assessed.

The guidance manual provides the assessor with the information needed to carry out a risk assessment, including:

- general concepts on environmental risk assessment and the steps undertaken;
- what data are required;
- how data are evaluated for adequacy, suitability and reliability;
- how environmental exposure is assessed;
- how environmental effects are assessed;
- how persistent, bio-accumulative and toxic chemicals are assessed; and
- how risk is characterised and what can be done to manage risk.

CASE STUDY: Tailings management at Iron Ore Company of Canada (IOC)

The Iron Ore Company of Canada (IOC), part of the Rio Tinto Group, has operated a mine and associated processing facilities at the Carol Project in Labrador City since 1962. During this time IOC has deposited tailings within a designated portion of Wabush Lake, as allowed by government authorisations.

IOC tailings are non-acid generating, with an average of 20 per cent solids, 17 per cent iron. The tailings consist of silica and quartz, including a significant loading of colloidal-sized, iron-stained quartz particles which impart a cloudiness or turbidity (red water effect) on the entire Wabush Lake system.

The deposition of tailings within the lease line and the unconfined spread of the colloidal particles throughout the lake have negatively impacted the benthic habitat within Wabush Lake. The red water also has a negative impact on the visual amenity of the lake, resulting in negative public perception and restricting the commercial or recreational use of the lake.

IOC was one of the first mining companies in Canada to implement an environmental effects monitoring (EEM) program to assess and understand the potential impacts of its operations on the receiving environment, water quality and ecological values. The EEM program found that the fish populations were healthy and abundant, with no significant differences observed between Wabush Lake fish and fish from control lakes. IOC

effluent has passed all acute toxicity tests (rainbow trout) that have been conducted on a regular basis since the 1980s.

Increased public awareness on tailings management and new federal legislation on tailings deposition in 1999 resulted in a review of IOC's tailings management practices. After an exhaustive options review process—which involved extensive risk assessments built around environmental protection, sustainable development and community consultation—IOC selected a preferred option to (a) ensure compliance with pending federal legislation and (b) meet the social and community expectations and commitments to improve the recreational and ecological values of Wabush Lake.

The preferred option, to construct a 15-kilometre long dyke within the Wabush Lake system and effectively isolate up to 50 per cent of the lake from other potential uses, was the lowest-cost option selected by all stakeholders (including community) to deliver both regulatory compliance and the social/community objectives to restore the ecological and recreational values of Wabush Lake. However at \$250 million it represented a very significant capital investment with minimal return to shareholders.

Ongoing stakeholder consultation, particularly within the local Labrador City community, continued to highlight potential improvements to the project. As a result, IOC was able to obtain regulatory approvals to amend the project at several stages of design to deliver an improved project that addressed all stakeholder criteria.

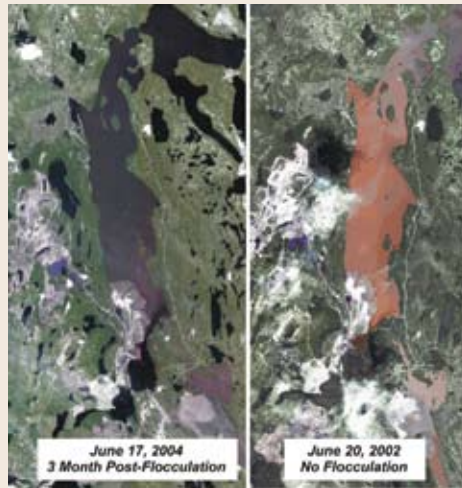
The most significant change to the approved project involved the use of flocculation for control of tailings deposition and to facilitate the removal of the red water effect on the lake system. Although early assessments of this technology proved inconclusive due to technical problems, a four year R&D program was established to address these issues because it was evident this technology would provide a much improved solution to the approved base case.

The flocculation R&D program was augmented by a wide range of environmental studies to address all regulatory and stakeholder concerns, including approval of the flocculation agent. In 2004, a four-month, full-scale flocculation trial was conducted and the outcomes of this trial clearly demonstrated the application of flocculation to be a superior outcome—meeting the IOC commitment to restore the ecological and recreational values of Wabush Lake while meeting all regulatory requirements (Figure 1).

As a result of the R&D outcomes and the high level of integrity and transparency in the stakeholder consultation process, IOC was able to successfully modify the approved project and to streamline the regulatory approvals process to ensure sufficient time for construction activities to meet compliance deadlines. A significantly better environmental outcome was achieved, is more sustainable in the long term, and at a significantly lower cost to the company.

One of the key successes of the project was the constant consultation process with regulators, community and other stakeholders throughout the project optimization

phases to keep them informed of activities and obtain their feedback on proposed optimizations with respect to community and legislative requirements.



Before (left) and after flocculation (right). Image source: Rio Tinto

3.2.3 Community health risk

These risks address potential impacts from an operation's activities that may affect the health of the local community. This type of risk generally relates to mining or mineral processing operations' emissions to air, water or land.

The onset of social health pandemics may be correlated with the growth of an operation or project, through the migration of communities to the area, and the introduced cultural or social pressures which may evolve. For example, communicable diseases may spread from rapid expansion and migration of itinerant workers and communities. Where such community health issues are prevalent, mining companies may choose to fund health programs or provide community infrastructure in remote areas. Such an approach benefits the community and benefits the company since the health and wellbeing of the community and the company's employees is enhanced.

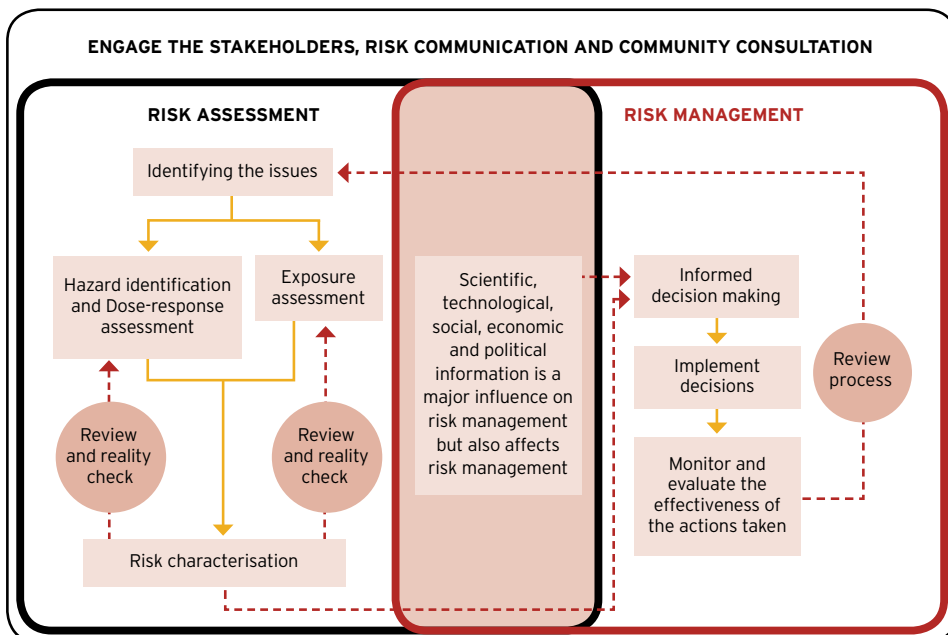
The *Environmental Health Risk Assessment Guidelines* for assessing human health risks from environmental hazards presents a framework that combines risk assessment, risk management and risk communication processes (Department of Health and Ageing and enHealth Council 2004). This framework specifies steps that are specific to environmental health risk assessment—in particular the inclusion of toxicology, epidemiology, exposure assessment and dose response assessment in the determination of risk to the general population, subgroups or individuals.

In 1983, the National Academy of Sciences in the United States developed a four-step paradigm for risk assessment and risk management as follows:

- **Hazard identification:** examining toxicity data to determine effects of a chemical on health of humans or other organisms.
- **Dose-response assessment:** extrapolating toxicity data from high-dose studies to predict the likely effect of low doses of the chemical (also referred to as hazard characterisation).
- **Exposure assessment:** magnitude, frequency and duration of exposure to a chemical (for example, exposures from proposed or actual manufacture, use or disposal of a chemical).
- **Risk characterisation:** estimates potential for, and magnitude of, risk to an exposed individual or population.

The enHealth Council includes these elements in its risk management framework. Figure 2 presents the *enHealth Risk Management Framework* and shows the relationships between environmental health risk assessment and risk management. Stakeholder engagement, risk communication and community consultation are overarching components.

Figure 2: enHealth Council Risk Management framework.



Source: enhealth.nphp.gov.au/council/pubs/pdf/envhazards.pdf

The *Environmental Health Risk Assessment Guidelines* provide a general environmental health risk assessment methodology applicable to a range of environmental health hazards, with a focus on chemical hazards. Links to risk management, community consultation and risk communication are identified throughout the document.

The Health Canada publication, *Investigating Human Exposure to Contaminants in the Environment*, which consists of two handbooks, provides useful information. A *Community Handbook* aims to help carry out a descriptive exposure assessment and develop a health profile for a community (Health Canada 1995b). A *Handbook for Exposure Calculations* describes the general methods followed for calculating human exposure to environmental contaminants (Health Canada 1995a).

The *Handbook for Exposure Calculations* describes a step-by-step process for calculating exposures to chemicals and radio-nuclides present in the environment. The methods presented may be of use to health professionals performing exposure assessments and may help the public understand the process and methods generally followed for performing exposure assessments (Health Canada 1995a).

These handbooks have been prepared by the Great Lakes Health Effects Program of the Health Protection Branch, Health Canada.

3.2.4 Regulatory risk

Changes to regulatory, legislative or compliance regimes can pose risks that are among the most challenging for the mining industry. If not addressed properly, these risks can have serious consequences including protracted permitting timeframes, prosecution, enforced shutdown, and production and reputation consequences. Both current and future risks at an operation need to be addressed. New and emerging legislation and requirements can create potential risks that the business needs to be aware of. Failure to recognise these new and emerging regulatory risks can limit an operation's business agility and ability to address change.

Pre-regulatory engagement can provide an early warning of potential issues and opportunities exist for businesses to pre-empt future legislation and gain a competitive advantage.

To a large extent, government regulation reflects public expectation. The expectation for regulatory change may be initiated locally, can be driven nationally by legislative frameworks or can be influenced by international trends. Regulation in other countries may also affect the Australian minerals industry directly through market restrictions.

Regulatory processes seek to ensure that workforce, community and environmental health are protected and that the public's 'right to know' about relevant risks is maintained. To date, regulations have been primarily framed around operational activities or 'licence to operate'. In more recent times, regulations are also being developed around 'licence to market' whereby risks related to downstream product use are also evaluated.

CASE STUDY: Government policy and regulation—licence to market

The increasing development of new regulations related to the access of products to markets, in part reflects the recognition of the value of a life cycle approach to production and use activities. The life cycle approach allows a holistic picture to be drawn on the differing contributions of phases of a product's life cycle to environmental costs and benefits.

The European Parliament agreed in 2006 to implement the Registration, Evaluation and Authorisation of Chemicals (REACH) legislation which came into force in June 2007. This legislation is aimed at striking a balance between the protection of human health and the environment, and maintaining industry competitiveness.

Under REACH, substances imported or manufactured in the EU will potentially need to be accompanied by new information requirements on health and environment risk related to their use in the EU. This legislation places the onus on suppliers/importers to build new information for their affected products and register these products with the new European Chemicals Agency (ECHA). The minerals industry has responded by forming commodity consortia to address the information needs for metals and minerals products. These groups will seek to fill information gaps for minerals and metals products as efficiently and cost-effectively as possible. The minerals industry is also well represented alongside government and academic expertise, on expert technical groups charged with the diverse aspects of REACH implementation.

The impact on the minerals industry of REACH is real, because information for high-tonnage imports such as minerals needs to be provided much sooner than similar information for lower tonnage chemicals, which may be potentially more hazardous. The US EPA requires similar data for high production volume substances.

Alongside the development of REACH, the United Nations has initiated the Globally Harmonised System (GHS) of classification and labelling of chemicals as a means of standardising chemicals classification schemes around the world, and already it has been implemented in several countries. In this context, the minerals industry has embarked upon the extensive revision of its product safety data sheets to ensure compliance with GHS needs.

A more specific example of European Union legislation that impacts directly on the electronics industry and indirectly on the minerals industry is the Restriction of Hazardous Substances Directive that became operational in Europe in July 2006. Under this legislation, all electronic equipment sold in the EU must be free of certain banned substances specified in the Directive. The main principle of the legislation is the

producer-polluter is responsible. Producer-polluters must ensure that the products they sell in the EU do not breach the trace % levels of each pollutant at whole unit level and must have systems and audit trails in place to prove conformity. These must cover the entire supply chain and manufacturing cycles (Lea 2003, www.rohs.eu/english/index.html, www.nemi.org/projects/fis/RoHS.pdf).

Interest in product legislation is also developing in economies outside the European Union. The emergence of China as a world economic power has meant boom times for mineral exporting countries but, at the same time, this trade is occurring in the context of new regulations. One example is the Harmful Content of China Imported Copper Concentrates (No. 49/2006), under the China Import and Export Inspection Act. This regulation now limits the arsenic, fluorine, cadmium and mercury content for copper concentrate imported by China. Importers whose first cargoes fail testing procedures may find the unloading of subsequent shipments delayed until test results for the current shipment are available. China depends on imported copper concentrate for around 75 per cent of its copper needs.

The emergence of new product-related legislation in several countries presents risks for all exporters, including minerals exporters. Those industries that proactively embrace the new information requirements for imported products will potentially be advantaged in the marketplace. Those importers who delay may find the market access of their products restricted.

3.2.5 Production risk

Production risk must be managed to control and sustain operational activities or to benefit from an identified opportunity. Production risks are identified in areas of the process that impact production volume or product quality and, ultimately, the cost and revenue of the business. These risks are largely economic in nature, but may be closely associated with non-economic risks. For example, social and environmental compliance issues may be triggered by a change in production. Similarly, environmental and social concerns may impact production. For example, mining or processing activities may need to cease if the wind is blowing emissions towards a population centre.

Some examples of production risk are pit failure or underground collapse, causing ore flow to stop or be restricted; major plant or equipment failure, causing prolonged plant shutdown and resources and reserves re-estimation due to fall in metal prices.

3.2.6 Risk to reputation

Risk to reputation is in some respects a flow-on consequence from most of the other risk categories. Effective risk management is likely to have a positive impact on an operation's reputation, offering new opportunities for growth, sustained activity and access to new markets.

Poor risk management—or a lack of identification and analysis of the potential consequences—may impact negatively on reputation and can lead to the premature cessation of mining and mineral processing activities if reputation is damaged to the extent that the local community, government and/ or stakeholders take action against the company.

In the context of product marketing, responsible producers also value the mantle of 'supplier-of-choice' which reflects positively on the whole company and not just upon a specific mining operation.

Positive reputation can be built and enhanced by performing well in the eyes of stakeholders, but this can only be achieved through effective risk communication (see Chapter 8). The technical approach to risk assessment is to determine the probability of a risk and its consequence. For many environmental, social and sustainability issues, however, this approach to risk fails to recognise the views of stakeholders and can often lead to significant controversy—one side says it's perfectly safe while another says it's too risky. American risk communication specialist, Peter Sandman, developed an approach to risk communication whereby he defines risk by combining 'hazard' with what he terms 'outrage', to give:

$$\text{Risk} = \text{Hazard} + \text{Outrage}$$

The Sandman approach is based on an understanding of the psychology of the risk situation (from a range of stakeholder viewpoints) and designing a risk communication process around this understanding.

Risk communication is discussed in more detail in Chapter 8 of this handbook.

3.2.7 Financial impact (direct and indirect)

Financial impact or economic consequences should be evaluated (where practicable) for all risk types identified for an operation's activities. These consequences can be either negative or positive and should be assessed relative to the operation or project size, or in line with the company's definition of materiality.

Financial risks need to be assessed as they relate to capital expenditure, schedule, operating cost, production and revenue, all of which have the potential to affect the profitability and net present value (NPV) of the operation.

3.2.8 Risk at closure and post closure (legacy)

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

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

CASE STUDY: Using quantitative risk assessment to set post-closure financial assurances, Martha Gold mine, Waihi, New Zealand

Waihi Gold Company (WGC) has operated its open cut Martha mine in New Zealand since 1988. WGC applied for consents in 1997 to extend the Martha mine for a further seven years past the planned and consented end of mine life. Under the approvals process the regulator required a post-closure bond (financial assurance) that would last beyond the closure period.

The objective of the post-closure bond was to indemnify the people of New Zealand against the costs for site management and for prevention or remediation of environmental risk events that could occur in the future. The post-closure securities were to exist in perpetuity.

The anti-mining and environmental lobby groups stated that a bond in excess of \$100 million would be required. WGC wanted to post a bond that was proportionate to the level of post-closure risk.

WGC proposed that at closure, the land currently in and around the mine pit and the area occupied by the tailings and waste rock disposal facilities would be transferred to a specially capitalised charitable trust that would then assume responsibility for ongoing management and maintenance of the assets, and for remediation of any unplanned risk events.

Capitalization bond structure

The potential future costs to manage and maintain the site were divided into four categories:

Base costs: The costs of activities that were known and required—administration, maintenance, monitoring.

Public liability insurance: The cost of annual premiums for public liability (third party) insurance.

Industrial and Special Risk (ISR) insurance: The cost of annual premiums for the potential occurrence of insurable sudden risk events that were uncertain and were not expected to occur, but which could occur (for example tailings release or failure of pit lake outlet structure).

Gradual risk issue costs: The potential cost of uninsurable gradual risk events that were uncertain and were not expected to occur, but which could occur (for example, pit lake water quality deterioration, acid rock drainage seepage, dust emissions) and were either not insurable or not cost-effectively insurable.

Estimation of the base costs of the known activities to manage and maintain the site, and estimation of the public liability insurance costs was relatively straightforward and the costs were estimated in the usual way using discounted cash flow to generate this component of the capitalisation fund.

The challenge for the project was to estimate a reasonable, yet conservative dollar value to reserve for ISR insurance and for the potential occurrence of uninsurable gradual risk events.

Risk assessment

A formal risk identification process was performed using an expert panel comprised of WGC section managers and external specialist expertise. The disciplines represented were geochemistry, hydro-geochemistry, hydrogeology, law, and engineering (mining, tailings dam, environmental, milling, water treatment and geotechnical).

The panel identified around 95 credible risk events that included, for example, pit wall stability, settlement, blasting impacts, damage to heritage assets, noise, pipeline bursts, chemical spills, regulatory change, soil contamination, dust, hazardous materials, wildlife impacts, traffic, visual impact and property values.

Many of the identified risk events were excluded from consideration for the post-closure bond on the basis that they only existed during mine operation and closure activities, and/or were improbable or inconsequential following closure.

The 10 post-closure risks that were included in the post-closure bond analysis were: pit wall instability, pit lake outlet structure failure, pit lake water quality, collection pond water quality, tailings bypass seepage, waste rock bypass seepage, perimeter bund acid rock drainage, catastrophic release of tailings, seepage release, and tailings pond water quality.

The risk events were subdivided into the two groups: ISR and gradual. Sudden, catastrophic events were identified as being insurable and were included in the ISR grouping; the catastrophic release of tailings being the primary risk event in this group.

For the gradual risk events, a quantitative approach to risk modelling was used for the risk assessment. Risk is calculated at the product of likelihood and occurrence cost for each risk event. A risk cost, which formed the gradual risk component of the capitalisation fund, was calculated as the sum of the occurrence cost of the highest ranked risk issues that contributed to 95 per cent of the total risk for that group.

Capitalisation bond amounts

Post-closure base cost

The estimated base cost of the known activities to manage and maintain the site was \$550 000 (NPV).

Public liability insurance cost

The cost to provide \$5 million cover was estimated to be \$130 000 (NPV).

ISR insurance cost

The ISR group risk cost (\$12 million) was used to explain and negotiate the ISR cover requirement to the insurance broker. The broker indicated that the required annual premium of \$45 000 to cover \$12 million, would cover up to \$50 million. This premium was then used to calculate the ISR component of the capitalisation bond. The NPV of an annual ISR premium of \$45 000 per year, discounted over the 50 years that the potential for a tailings release event was assumed to exist, was \$960 000.



Martha mine, Waihi, New Zealand. Image source: Newmont

Gradual risk issues cost

For the gradual component, the risk cost (\$4 million) represented the cost that should be reserved to cover the occurrence of gradual risk events post closure.

Conclusion

Using the above process, it was estimated that a total sum of around \$5.6 million would allow the trust to undertake its land management and maintenance responsibilities in perpetuity.

When the bond proposal was put to the regulators, the bond structure and quantum were accepted without challenge. In the subsequent Environment Court hearing, the judge chose to round the amount up to \$6 million, and WGC posted a capitalisation bond of that amount.

The process is subject to annual review and WGC will have the opportunity to re-evaluate and modify its post-closure risk profile. There is an expectation that, over time, this focus will enable the capitalisation bond to be further reduced.

3.3 Enterprise-wide risk management

Risk profiles can be highly complex for large businesses that may be operating nationally or internationally and in a range of different social, political and geographic environments. The concept of materiality is used within organisations to clarify the significance of risk situations to managers at different levels of responsibility and accountability. Enterprise-wide risk management systems are developed around the materiality concept to provide a framework for managing the wide variety of risks faced by the organisation. Such a system enables more informed decisions to be made for business sustainability.

3.3.1 Risk and materiality

Clearly defined risk acceptance criteria are required to determine what risks can be tolerated, and what risks are material or significant to the operation and to the community and, therefore, need to be managed. The significance of the risk to the operation and the community (and how much risk they are willing to accept) depends on the benefits which are expected from addressing the risk, together with an understanding of the operation's cultural attitude towards risk and how it may limit its exposure to the varying types of risk.

Materiality and risk

To be applied effectively, the risk management process requires substantial management involvement and functional specialist time and effort.

The rewards, however, of effectively integrating a robust risk management process into a site's management framework are significant—particularly if, through risk management, the site avoids the impacts of a catastrophic event.

The concept of materiality is used to ensure that the robust risk management process is applied to those issues that can significantly impact on an operation, its people, the environment or local communities and, therefore, warrant a specific management focus.

Without effectively defining materiality, a site's risk register can grow uncontrollably to include almost trivial issues over which management oversight is not required. The risk management process can then degenerate into a quest for compliance rather than being a valuable management tool.

Materiality defines what needs to be included in the asset's risk register, what needs to be actively managed and what needs to be reported up through the organisation.

It is the responsibility of management to set materiality thresholds for the business.

Materiality thresholds for risks should be established in terms of likely impact.

Materiality should be defined for impacts to the health and safety of employees and the public, the environment, the local community and the continuity of operations. Where a common approach to risk rating is used, materiality can be also defined in terms of a threshold residual risk rating.

As an example, materiality thresholds for a site could be defined as any risk issue that could cause:

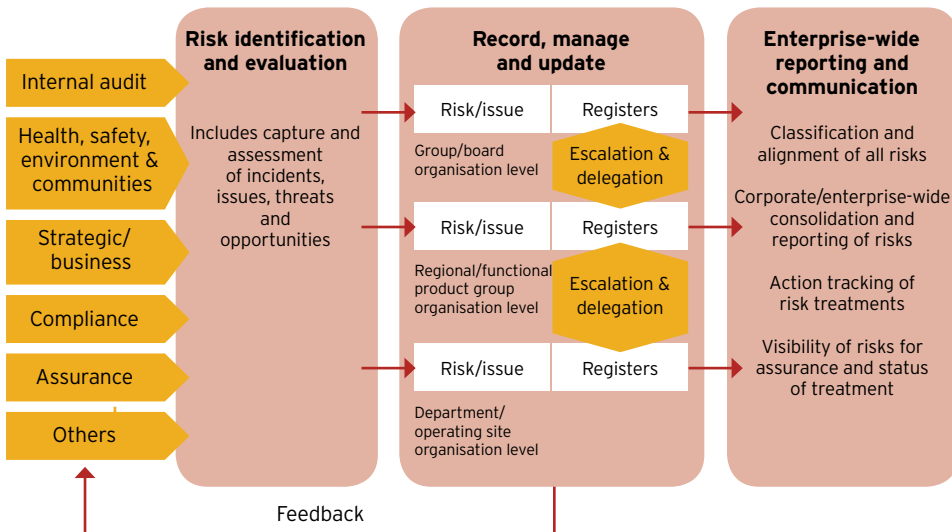
- unrecoverable loss of more than one month's production;
- a financial loss of more than \$5 million;
- a serious injury resulting in a disability that prevents return to work;
- a fatal injury;
- long-term health impairment to an exposure group within the workforce or local community;
- substantial irreversible damage to the local environment; and
- multiple community complaints, media attention and loss of reputation.

3.3.2 Enterprise-wide risk framework

For global businesses, obtaining a group-wide risk profile by aggregating summary risk metrics of different local systems is a major objective in addressing their risk management needs. Businesses are finding that they need to manage risk in a more proactive way to avoid losses and gain advantage in an increasingly competitive environment. An enterprise-wide risk framework should allow a business to determine how it could be affected by a particular risk in order to let the business make faster decisions and to see the whole impact of a particular event or scenario.

Figure 3 illustrates the connectivity between risk types, their analysis, management, and communication, in order to consolidate and prioritise risk treatment and acceptance at the enterprise level.

Figure 3: Generic framework for enterprise-wide risk management.



Source: Anthony Butcher (Rio Tinto)

An enterprise-wide risk framework can enhance the basis for decision making through a clearer articulation of businesses objectives, more focused management information, and a better understanding of the trade-offs between risk and reward. Effective risk management provides the assurance that risks are being identified and controlled. It also enables the business to capitalise on opportunities.

The boards of companies, in particular those of global organisations, have become more concerned with ensuring that their management teams have robust and 'fit-for-purpose' risk management processes in place. Boards expect risk profiles to be known and that mitigating processes are in place, to give reasonable comfort that serious incidents do not occur within the companies for which they are responsible.



4.0 RISK MANAGEMENT PROCESS

Purpose

This section presents the key elements of the AS/NZS 4360:2004 Risk Management Standard and outlines its application to all stages of mine life and the materials value chain.

KEY MESSAGES

- The main elements of risk management, as outlined in AS/NZS 4360:2004, are: (1) communicate and consult, (2) establish the context, (3) identify risks, (4) analyse risks, (5) evaluate risks, (6) treat risks, (7) monitor and review.
- Mining and processing project risks must be identified and managed at all stages of an operation's life cycle.
- Significant risks that are defined, communicated, understood and satisfactorily addressed early in the mine life cycle are more likely to be accepted as well managed by stakeholders who have an interest in the mining project.
- Materials stewardship provides a central framework for an integrated risk approach to responsible management of materials used in mining and mineral processing, particularly wastes, hazardous substances and products.

4.1 Introduction

This section presents risk management as a key business process that is applied with rigor throughout the Australian minerals industry. The most commonly applied approach is provided by the *AS/NZS 4360:2004 Risk Management Standard and Guidelines* (Standards Australia: 2004a, 2004b). The AS/NZS 4360:2004 approach will form the basis for the remainder of this handbook as it provides an overarching framework and generic guide for managing risk. It is also well accepted throughout industry. Other approaches have been developed and are sometimes applied within the minerals industry, but usually these approaches apply to specific risk types. Some of these approaches have been referenced in Chapter 3 in relation to specific risk types.

4.2 Risk management process

Most managers and technical professionals associated with the Australian minerals industry will be familiar with risk assessment processes and a broader risk management framework encompassing identification, analysis, evaluation and treatment of risks.

Historically, risk management approaches have focused on the technical aspects of risk management. Contemporary risk approaches (including AS/NZS 4360:2004) now place more emphasis on communication processes at each stage of risk management. It is important for risk practitioners and managers to fully appreciate the relationship between effective risk management, risk communication and the technical risk assessment process. See Chapter 8 for a more detailed discussion on risk communication.

Risk management process

The main elements of risk management, as outlined in AS/NZS 4360:2004, are:

(1) Communicate and consult

Communicate and consult with internal and external stakeholders as appropriate at each stage of the risk management process and concerning the process as a whole. AS4360 requires this all the way through the risk process.

(2) Establish the context

Establish the external, internal and risk management context in which the rest of the process will take place. Criteria against which risk will be evaluated should be established and the structure of the analysis defined.

(3) Identify risks

Identify where, when, why and how events could prevent, degrade, delay or enhance the achievement of the objectives.

(4) Analyse risks

Identify and evaluate existing controls. Determine consequences and likelihood and, therefore, the level of risk. This analysis should consider the range of potential consequences and how these could occur.

(5) Evaluate risks

Compare estimated levels of risk against the pre-established criteria and consider the balance between potential benefits and adverse outcomes. This enables decisions to be made about the extent and nature of treatments required, and about priorities.

(6) Treat risks

Develop and implement specific cost-effective strategies and action plans for increasing potential benefits and reducing potential costs.

(7) Monitor and review

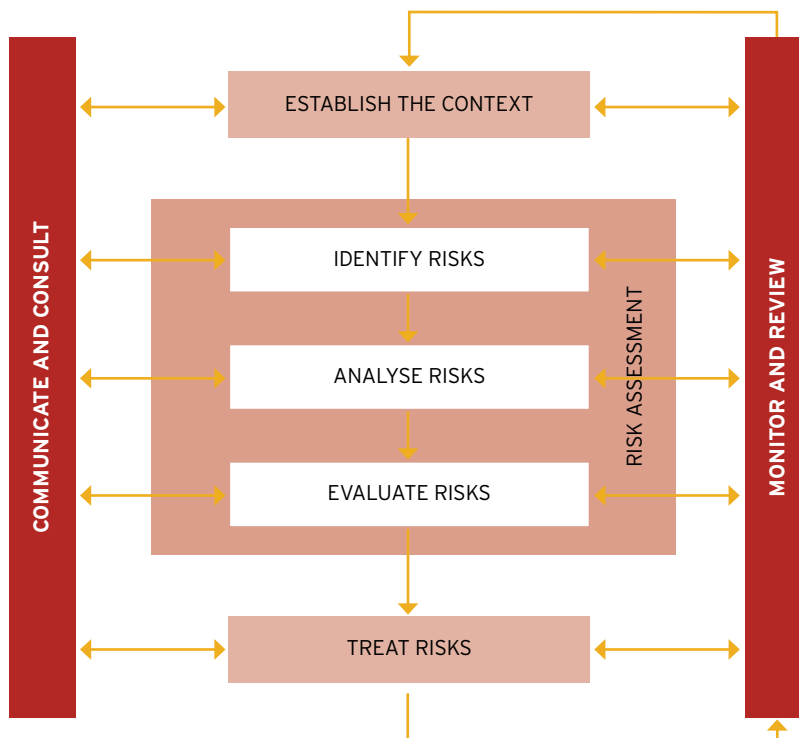
It is necessary to monitor the effectiveness of all steps of the risk management process. This is important for continuous improvement. AS/NZS 4360:2004 requires this all the way through the risk process.

Risks and the effectiveness of treatment measures need to be monitored to ensure changing circumstances do not alter priorities.

Source: AS/NZS 4360:2004.

Figure 4 outlines the AS/NZS 4360:2004 Risk Management Standard process for identifying, analysing and managing risks, including technical risk. It also emphasises the importance of stakeholder engagement, risk communication and community consultation processes at each stage.

Figure 4: AS/NZS 4360:2004 Risk management steps.



Source: Australian/New Zealand Risk Management Standard (AS/NXS 4360)

4.3 Applying risk processes to all stages of mine life

Mining and processing project risks must be identified and managed at all stages of a mine life cycle. The principal stages of a mine development are:

- exploration and discovery;
- concept, order of magnitude, pre-feasibility, feasibility, design and project approval;
- construction and commissioning of mine and mineral processing facilities;
- operation and production;
- closure, decommissioning and rehabilitation;
- post-closure monitoring.

Each stage presents significant challenges for the mining company from a risk management perspective.

It is essential that a mining/processing operation evaluates its technical risks wherever possible. Many mining companies today employ a risk process to help identify and weigh operational risks, before allocating resources to address priority risks. Listening to the questions and concerns a broad range of stakeholders will help the mining company define the scope of the risk management process.

If potentially affected stakeholders have concerns that are not adequately addressed by the mining company, then relationships will be damaged—often for the long term. Once trust is lost, it may be very difficult to regain.

Where a significant risk has been identified, key questions that must be asked by the assigned risk manager are:

- Which stakeholders could be affected or are likely to have an interest in the risk?
- Which stakeholder groups could perceive the risk differently?
- What are the various stakeholder expectations and understandings in relation to the risk?
- What are the legal requirements?
- What technical solutions to risk minimisation can be employed?
- What risk communication strategies should be applied for the various stakeholder groups?

These questions are applicable to all stages in the mine life cycle.

Stakeholders are more likely to accept that significant risks are well managed if they are defined, communicated, understood and satisfactorily addressed early in the mine life cycle. This can only occur if those stakeholders are identified in the first place—an essential first step. Some types of stakeholders have an interest in the mining project throughout all stages. For example landowners and neighbouring property owners. Other stakeholder groups may only have an interest for one or two stages of the mine life. For example, employees and their families, suppliers and customers have a direct interest in the mine during its operating life.

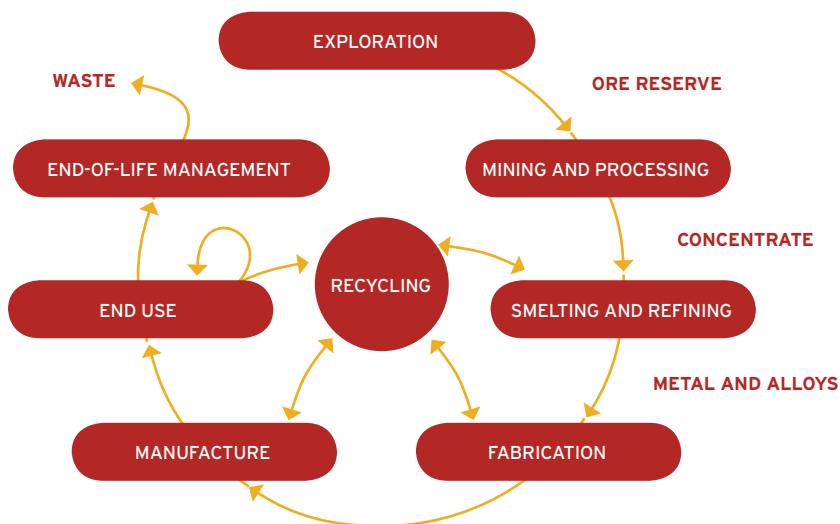
Effectively applying risk management principles early lays the foundation for good relationships throughout the whole mine life cycle. There are many examples of relationships being damaged at the exploration/discovery stage or during mine feasibility. This creates difficulties for stakeholder relationships that can carry through to the construction, operational and closure phases of mining and may require significant additional management effort, delay project start-up or adversely affect the life of the mine. As technical solutions to risks are planned and implemented, the effectiveness of these solutions should be canvassed among stakeholders in order to maintain and build confidence in the risk management process.

4.4 Applying risk processes to the materials value chain

Stewardship is the management of materials, resources and products throughout their life cycle to maximise value and better manage the environmental and social impacts arising from their production and use (Australian Government 2006a). The materials stewardship approach has the potential to provide a central framework into which other critical functions, such as risk management, can be linked, due to its focus on creating integrated systems for managing materials throughout their life cycle, particularly wastes, hazardous substances and products,. Figure 5 illustrates a generic example of the materials value chain.

With increasing awareness of the potential hazards arising from the use or inappropriate disposal of some materials, there is a need for proactive industry action on materials stewardship. This challenge is already being addressed by some companies, in their conduct of comprehensive life cycle assessments for their key products.

Figure 5: Generic materials stewardship value chain for the minerals industry.



Source: Rio Tinto

Failure of the industry to properly respond will likely lead to materials management principles being imposed through regulation, for example, REACH in the European Union and the NSW Extended Producer Responsibility Regulations in Australia.

The materials stewardship value chain assists in the identification of chemical substances that are present in the ore supplied and used in mineral processing; emitted in primary mineral processing or downstream refining, smelting, and manufacturing; or emitted during disposal or recycling processes at the end of product life. The following questions can help to identify chemical substances that could impact on human health or the environment:

- What are the chemical and mineralogical characteristics of the ore at extraction, including valued substances and naturally-occurring impurities?
- What chemicals are supplied and used in the mineral processing operation?
- How are the processing chemicals manufactured, transported and stored prior to use?
- What emissions of interest occur in the mineral or metal extraction process and subsequent processing?
- How are emissions controlled?
- How are hazardous waste streams managed?
- What impurities of interest are contained in product that is sold and transported to customers?
- Are there any processing chemicals of concern to stakeholders (cyanide)?
- What is the fate of chemical substances in product?

Once this information has been collected, minerals supply chain (upstream and downstream) stakeholders who are interested in chemical substances can be identified. These stakeholders (community, regulators, suppliers, customers, manufacturers, transporters, plant operators) need to be provided with information on the chemical substances of interest, such as:

- properties of chemical substances present, whether naturally occurring in the product or added;
- possible exposure pathways and necessary controls to protect employees and the community;
- available options for reducing, recycling, denaturing, and disposal of priority substances;
- emergency preparedness and response procedures; and
- responsibility to inform correct transport, storage, handling and use procedures.

Materials stewardship concepts provide a basis for defining the flow of materials and chemical substances related to mining and mineral production and this helps to identify stakeholders along the materials supply chain who may need to be involved in risk management activities.

While the initial steps of a materials stewardship approach will provide useful data for risk management, the broader focus on managing material flows throughout the value chain in

partnership with other users provides powerful tools for managing overall risks to community and environmental health.

CASE STUDY: RightShip

Rio Tinto and BHP Billiton seek best practice stewardship in their own operations and throughout the product supply chain, ensuring that products are stored and transported safely and in an environmentally sound manner.

Shipping is a key focus for Rio Tinto and BHP Billiton, who annually transport millions of tonnes of product by sea to customers around the world. For many years, both companies have invested heavily in ship vetting processes to gather information, check the quality of ships nominated to carry cargoes and minimise shipping risk.

In 2001, the two companies combined their considerable vetting expertise to form RightShip Pty Ltd—BHP Billiton (50 per cent) and Rio Tinto (50 per cent). As a specialist vetting company, RightShip offers a uniquely comprehensive online system, backed by a global network of vetting experts offering advice and providing enhanced services.

RightShip vets every ship that Rio Tinto and BHP Billiton use to move their cargoes.

Each time a ship is nominated, it appears in the online system and its suitability for the task is evaluated against more than 40 criteria, covering the ship's structural integrity, history and the competence of its owners, managers and crew.

The ship is immediately rated acceptable or highlighted as requiring further review. It is a vital decision support tool, delivering critical information immediately to assist fast, appropriate decision making.

Rio Tinto and BHP Billiton identified the need for such a system when the global shipping industry experienced unacceptable human, environmental and financial losses. Dry bulk shippers were plagued by ageing, poor quality ships. During 1990 to 2000, 730 seafarers died, 160 vessels were lost, and 888 serious casualties and 2879 minor casualties occurred.

As two of the largest shippers of dry bulk products, Rio Tinto and BHP Billiton found it desirable to manage their own risk. Although commercial competitors, these companies had common goals—they wanted to manage their own risks effectively and efficiently, and eliminate sub-standard ships and operators from the industry, thereby ensuring companies with quality ships and crews would not continue to suffer commercial disadvantage.

To increase pressure on high-risk ships and operators, RightShip makes its valuable expertise available to anyone seeking vetting support. RightShip now serves more than

50 client organisations. In 2005, RightShip vetted 9162 ships online, representing about 827 million deadweight tonnes of cargo; inspected and assessed 431 ships; and excluded 165 high-risk ships from clients' supply chains.

RightShip illustrates appropriate stewardship, as Rio Tinto and BHP Billiton have invested significantly in managing risk and protecting vital human and environmental resources for their own benefit and to influence broader improvement in the industry.

A globally significant company, RightShip has clients in 45 countries.

The key lessons learned from RightShip's success are:

- identify an urgent need and developing an innovative and uniquely valuable response;
- think broadly to maximise impact and seek alliances based on common interests, even among commercial competitors; and
- give passionate, expert people the resources to build on innovative ideas and keep improving their application within the company and in alliance with others.



Bauxite Shipment to Alumina Refinery, Gladstone, Queensland. Image Source: Rio Tinto Alumina Ltd.



5.0 RISK ASSESSMENT IDENTIFYING AND DEFINING RISK

Purpose

This section discusses context setting and presents the methods for identifying and defining risk.

KEY MESSAGES

- Setting the context of a risk assessment establishes the background to the risk management process, the nature of the activities and the range of potential impacts.
- A clear understanding of risk and the factors that contribute to risk is required in order to identify and describe risk, and analyse its potential impact on the environment, an organisation or an activity.
- Risk identification workshops are designed and facilitated by a specialist risk analyst. The facilitator ensures that information obtained is directly relevant to the risk assessment, appropriate processes are followed and time and resources are used effectively.
- Risk registers are used to present risk information: to document the outputs from the risk identification process and to present the results of risk analysis and strategy development.

5.1 Introduction

This chapter deals with context setting and risk identification. Chapter 6 discusses the tasks of risk analysis and assessment. Various risk analysis tools are discussed throughout the chapter as individual concepts.

The need to analyse risk can come from a number of drivers, many of which will dictate the type of risk assessment method to be used or prompt the requirement for a more quantitative level of assessment. To help identify the relevance and materiality of the risks and set the management context, the risk analysis drivers need to be defined and communicated upfront. The following broad category prompts are commonly used by businesses to establish the need for and scope of risk management processes:

- stage in project life cycle (concept, pre-feasibility, feasibility, construction, commissioning, operations, closure);

- legal or regulatory requirements;
- stakeholder concerns;
- change management;
- hazard identification;
- audit findings;
- monitoring data; and
- incident investigations.

Once this need is identified, the context must be established to determine the appropriate assessment methodology and, ultimately, how the risk will be managed.

5.2 Establishing the context

Setting the context of a risk assessment establishes the background to the risk management process, the nature of the activities and the range of potential impacts. This process leads to identification of key stakeholders and formulation of the risk management aims and structure. The scope of the risk management process is then defined.

The first step is to understand the activity being analysed for risk and describe the significance to the business. The aims of the risk assessment can be developed from this information. Risk analysis aims to assess the risk posed by a number of activities and situations within the minerals industry. For example, project work within the organisation, the risk posed by an activity to the wider environment (environment impact statement applications), estimation of the financial cost of risk events, public safety risk, worker safety risk, selection of least-risk options, determination of financial assurances (bonds or trusts), estimation of risk transfer through acquisitions and divestments, and assessment of enterprise-wide risk.

For project evaluations, a comprehensive description is required that clearly articulates the aims, benefits and costs of the project, the activities that will be carried out, when they will be carried out, new infrastructure, changes to existing infrastructure, interfaces with existing operations, and potential impacts of the project.

The aims of a risk assessment determine the types of output required and the approach taken. A range of methodologies are available from qualitative, semi-quantitative to quantitative approaches. The aims will also determine the detail required. Risk assessments can be used for corporate overviews, to prioritise risks and screen options to define management focus, or applied to specific events or planned tasks.

The context description and aims of the risk assessment also help determine what structure is required for the risk assessment, and the nature and levels of expertise (subject matter specialists, names, experience, reputation, conceptual capacity) required to identify and describe key risk events.

5.3 Risk identification

A clear understanding of risk and its contributing factors is required in order to identify and describe risk, and analyse its potential impact on the environment, an organisation or an activity.

The aim of the risk identification process is to understand all the key risk events that are relevant to a project, activity, or other situational context; define their cause-and-effect relationships; identify the nature and extent of all potential consequences (for example, financial, environmental, social, economic, safety); and understand their likelihood for occurring.

As defined in Chapter 2, in general terms, risk is a combination of likelihood and consequence. A risk event with severe consequences may not pose high risk because the consequence of the event may have an extremely low chance of occurring. Similarly, a highly likely event may also not pose high risk because its consequences may be very small. In addition, a low-consequence event which is highly likely to occur may pose similar risk to a high-consequence, low-likelihood event. Chapter 6 further illustrates these scenarios through the application of risk assessment methodology.

All information obtained during the risk identification process is used in the subsequent risk analysis and assessment (Chapter 6).

5.4 Process for identifying risk events

Most risk information is obtained from experienced operators and subject matter specialists who jointly understand the activities that will be carried out, and their potential impacts on the business and the assets within the wider environment.

Information from experts is most often obtained during specifically convened workshops and subsequent, ongoing follow up and consultation with experienced operators, specialists and their teams.

External stakeholders are consulted when risk situations can have broader community consequences and a range of stakeholder viewpoints are required to better define risk.

5.5 Risk workshops

Risk identification workshops are usually designed and facilitated by a specialist risk analyst. Benefits of a workshop approach for identification of risks include:

- information obtained is directly relevant to the risk assessment;
- appropriate processes are followed; and
- effective use of time and the available expertise.

Prior to a workshop, the risk analyst—in consultation with the project manager (or risk owner)—will obtain a good understanding of the project, review available data, develop a preliminary list of risk events, develop preliminary cause-effect relationships (event trees), and will have developed the structure of the risk assessment to the point where a preliminary risk assessment model (qualitative or quantitative) can be produced.

Workshops can vary in length from a few hours to a few days (depending on context and scope) and follow an agenda. The agenda normally begins with introductions, a safety briefing, summary of context, introduction to the risk assessment approach to be used, the role of the participants, required outputs from the workshop, and a briefing on how the available information will be used in the risk assessment process.

The workshop initially focuses on identification of risk events. The preliminary list of risk events is usually presented at the meeting and the participants are then requested to engage in a brief brainstorming session to add to the list, without much discussion.

For the remainder of the workshop (most of the allocated time), a facilitator systematically leads the participants through the complete list of risk events. During the process, the participants describe the cause and effect pathways, also referred to as risk scenarios, and describe their range of potential consequences and the likelihoods.

To define consequences, the operators and subject matter specialists are asked to describe the nature and magnitude of consequences should a given risk event actually occur over the given timeframe. Their judgements are often based on:

- previous events on site, at other organisation sites, or within industry locally, regionally and globally;
- previous events in other business contexts and environmental settings; and
- judgment from their own and industry experience.

A key requirement is to understand and describe the uncertainty related to the magnitude of all types of consequences. For qualitative risk assessments, participants may be asked to justify their decision on consequence, based on what is most reasonable.

In semi-quantitative risk assessments uncertainty can be accounted for by providing a very conservative high estimate of consequence to the nearest order of magnitude. Consequence tables can also be used to assist in identifying consequences in a consistent manner for given sets of assets or impact types (see Chapter 6 for a discussion and examples).

In more quantitative cases the participants are requested to provide a range of consequences. In other cases where the judgement will be used to define a probability distribution, the participants are asked to provide their best estimate, plus a very high estimate of the consequence magnitude.

The workshop concludes when all risk events have been discussed and have either been included in the risk assessment or have been excluded on the grounds that they were either not relevant, possible, or of material consequence.

5.6 Documentation

The outputs from the risk identification process need to be documented in order to:

- communicate all risk events considered;
- be used as a work-back reference when developing strategies to identify key intervention points and develop appropriate actions;
- be used as reference when reviewing risks after some time has elapsed (changed circumstances due to strategy implementation or changed business, environment, regulatory, social conditions); and
- keep a record for due diligence purposes.

In most cases, the risk assessments require full documentation of the process, the judgment values (likelihoods, costs, impacts), the rationale behind judgments, and the parties responsible for providing each judgment.

Risk registers are commonly used to present risk information. Risk registers are used to document the outputs from the risk identification process and to present the results of risk analysis and strategy development.

Typical contents of risk registers include:

- a tabulation of the risk events considered, events excluded, likelihoods and consequences;
- the results of risk analysis and evaluation (risk ranking or grading); and
- existing control measures, planned management actions, allocation of responsibility, timing of actions.

Table1: illustrates the types of fields normally recorded in a risk register.

Outline of a risk register

The following information needs to be provided for each identified risk:

- unique reference number
- date of last risk update
- brief title of the risk
- description of the risk
- materiality of the risk
- assessment of all types of consequences
- likelihood of occurrence
- risk rating determined from the likelihood and the highest consequence
- risk responses together with their current status
- risk owner.

To provide an audit trail and to assist in learning for future risk analyses, the risk register must retain information on all closed risks.



6.0 RISK ASSESSMENT: ANALYSIS AND EVALUATION

Purpose

This section outlines key methods of risk analysis and evaluation, and discusses when these methods should be applied.

KEY MESSAGES

- A wide range of risk assessment approaches are available to the mining industry. It is important that decision makers choose a risk assessment technique that is suited to their application and information needs.
 - Qualitative risk assessment techniques use descriptive terms to define the likelihoods and consequences of risk events. The methods are quick and relatively easy to use and they can provide a general understanding of comparative risk between risk events.
 - Semi-quantitative risk assessment takes the qualitative approach a step further by attributing values or multipliers to the likelihood and consequence groupings.
 - Quantitative risk assessment is being increasingly applied in the mining and minerals industry due to increasing business requirements to support financial decisions; make comparisons across financial, environmental and social risk profiles; and to demonstrate transparency, consistency and logic of approach. However, the application of quantitative risk outputs, which are often not immediately intuitive, requires some up-front learning investment by decision makers.
 - Quantitative risk assessment is used across the full range of risk applications—from deriving preliminary, first-pass separation of risk events, to much more comprehensive assessments. The comprehensive assessments can derive detailed risk profiles for priority ranking, cost estimates for risk events, input to financial models; and a basis for benefit-cost analysis.
 - Risk assessment is not a one-off process. Regular review of risk assessment outcomes is required.
-

6.1 Introduction

The objective of risk analysis is to produce outputs that can be used to evaluate the nature and distribution of risk, and to develop appropriate strategies to manage the risk.

Over the past 15 years, a considerable expansion has occurred in the strategic business importance placed on risk assessment and on the level of effort put into risk identification, analysis and ongoing management. Consequently, a range of risk management methods and expertise is available to the mining industry.

Organisations should select the combination of risk assessment and management options that is most appropriate to achieving their specific objectives within the times and budgets available.

Events or issues with more significant consequences and likelihood are identified as 'higher risk', and are selected for higher priority mitigation actions to lower the likelihood of the event happening and/or reduce the consequences if the event were to occur.

Qualitative methods use descriptive terms to identify and record consequences and likelihoods of events and resultant risk.

Quantitative methods identify likelihoods as frequencies or probabilities. They identify consequences in terms of relative scale (orders of magnitude) or in terms of specific values (for example estimates of cost, number of fatalities or number of individuals lost from a rare species). Monte Carlo simulation methods are often used to incorporate uncertainty into the quantitative estimates.

For both qualitative and quantitative methods, it is important to invest time in developing appropriate rating scales for likelihood, consequence and the resultant risk. The full range of risk situations likely to be encountered within the scope of the exercise should be considered when developing rating scales. The concept of materiality should also be used to define significance of consequences to the organisation as a whole and its management units. Clear descriptors need to be drafted for each level of likelihood and consequence to enable comparative judgements to be made. Different sets of descriptors can be developed for different types of consequence, and the equivalence of the different descriptors for each consequence level should be considered. If approximate equivalence cannot be agreed, separate consequence tables should be prepared for each consequence type. See Table 5 for an example of consequence ratings developed for a range of consequence types.

6.2 Qualitative methods

Qualitative approaches to risk assessment are the most commonly applied.

Qualitative risk assessment methods are quick and relatively easy to use, broad consequences and likelihoods can be identified, they can provide a general understanding of comparative risk between risk events, and the risk matrix can be used to separate risk events into risk classes (ratings).

A logical systematic process is usually followed during a qualitative risk assessment to identify the key risk events and to assess the consequences of the events occurring and the likelihood of their occurrence.

Qualitative risk assessment techniques use descriptive terms to define the likelihoods and consequences of risk events. An example from AS/NZS 4360 describes the magnitude of all consequences (or subsets of consequences such as economic, financial, environmental or social) as: insignificant–level 1, minor–level 2, moderate–level 3, major–level 4, or catastrophic–level 5. Similarly likelihoods can be determined as: almost certain–level A, likely–level B, possible–level C, unlikely–level D, or rare–level E. The meaning of these descriptions, in terms of the various consequence types and likelihood levels, then needs to be developed.

Outputs from qualitative risk analyses are usually evaluated using a risk matrix format, such as the example in Table 2. The risk matrix incorporates the pre-determined risk acceptance threshold and is used to determine which risks require treatment and the priorities that should be applied. Using the matrix, a risk rating for a given risk event can be selected by reading across and down the matrix using the assigned likelihood and consequence descriptors.

Table 2: Example of a qualitative risk matrix.

		Consequence level					
		1	2	3	4	5	
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic	Risk rating
A	Almost certain	A1	A2	A3	A4	A5	Extreme
B	Likely	B1	B2	B3	B4	B5	High
C	Possible	C1	C2	C3	C4	C5	Moderate
D	Unlikely	D1	D2	D3	D4	D5	Low
E	Rare	E1	E2	E3	E4	E5	

Source: Bowden, Lane and Martin (2001)

In the example matrix, there are 25 potential risk combinations and the risk outcomes have been divided into four risk levels (ratings). This type of matrix is typically used to compare risk levels for different events and to set priorities for risk treatment actions.

Qualitative approaches are best used as a quick, first-pass exercise where there are many, complex risk issues and low-risk issues need to be screened out for practical purposes. However, many organisations use qualitative methods for more comprehensive risk assessments.

However, qualitative approaches have some shortcomings compared with more quantitative approaches. Key criticisms are that qualitative methods are imprecise, it is difficult to compare events on a common basis, there is rarely clear justification of weightings placed on severity of consequences and the use of emotive labels makes it difficult for risk communicators to openly present risk assessment findings to stakeholders. Furthermore, the outputs from qualitative approaches are difficult to incorporate into financial business considerations.

6.3 Semi quantitative methods

Semi-quantitative approaches to risk assessment are currently widely used to overcome some of the shortcomings associated with qualitative approaches.

Semi-quantitative risk assessments provide a more detailed, prioritised ranking of risks than the outcome of qualitative risk assessments. Semi-quantitative risk assessment takes the qualitative approach a step further by attributing values or multipliers to the likelihood and consequence groupings. Semi-quantitative risk assessment methods may involve multiplication of frequency levels with a numerical ranking of consequence. Several combinations of scale are possible.

Table 3 shows an example of a semi-quantitative risk matrix where the likelihoods and consequences have been assigned numbered levels that have been multiplied to generate a numeric description of risk ratings. The values that have been assigned to the likelihoods and consequences are not related to their actual magnitudes, but the numeric values that are derived for risk can be grouped to generate the indicated risk ratings. In this example, Extreme risk events have risk ratings greater than 15, High risks are between 10 and 15, and so on.

Table 3 Example of a basic semi-quantitative risk rating matrix.

		Consequence level					
		1	2	3	4	5	
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic	Risk rating
5	Almost certain	5	10	15	20	25	Extreme
4	Likely	4	8	12	16	20	High
3	Possible	3	6	9	12	15	Moderate
2	Unlikely	2	4	6	8	10	Low
1	Rare	1	2	3	4	5	

Source: Bowden, Lane and Martin (2001)

An advantage of this approach is that it allows risk ratings to be set based on the derived numeric risk values. A major drawback is that the numeric risk values may not reasonably reflect the relative risk of events, due to possible orders of magnitude differences within the likelihoods and consequences classes.

In many cases the approach used to overcome the above drawbacks has been to apply likelihood and consequence values that more closely reflect their relative magnitude, but which are not absolute measures. The semi-quantitative risk matrix of Table 4 shows the relative risk values that would be derived by replacing the qualitative descriptions of likelihoods and consequences with values that better reflect their relative order of magnitude and provide more realistic relativity within each class.

Table 4: Example of an alternative, basic semi-quantitative risk rating matrix.

Likelihood level	Descriptor	Consequence level					Risk rating
		1	10	100	1000	10 000	
		Insignificant	Minor	Moderate	Major	Catastrophic	
1	Almost certain	1	10	100	1000	10 000	Extreme
0.1	Likely	0.1	1	10	100	1000	High
0.01	Possible	0.01	0.1	1	10	100	Moderate
0.001	Unlikely	0.001	0.01	0.1	1	10	Low
0.0001	Rare	0.0001	0.001	0.01	0.1	1	

Source: Bowden, Lane and Martin, 2001

In this example, the risk assessment clearly indicates that there is an order of magnitude difference between likelihood classes and also between consequence classes. Using this approach, it is possible to derive numbered risk levels by multiplying likelihood and consequence levels for each cell of the matrix. For example a risk event which is possible (likelihood level = 0.01) and would have a major consequence (consequence level = 1000) would show a risk level of 10. If the issues were comparable, then this event would pose the same risk as another event which was, for example, likely (0.1) but with lower, moderate (100), consequences.

The matrix of Table 4 also shows that, in this particular case, the risk ratings have been weighted to place more emphasis on higher consequence events. This is frequently done to reflect an organisation's lower tolerance of higher consequence events. This step can be difficult to justify and can be misleading in overemphasising some risk events (if the full range of consequences can be expressed in the same terms, such as dollars, for example).

Semi-quantitative risk assessment methods are quick and relatively easy to use, clearly identify consequences and likelihoods, usually provide a general understanding of comparative risk between risk events, and are useful for comprehensive risk assessments.

Where there is consistency between consequences levels, semi-quantitative approaches are particularly useful for environmental impact statement (EIS) risk assessments. A wide range of EIS stakeholders do not accept the results of fully quantitative risk assessments that use dollar values as the common term to reflect levels of consequences.

In these cases the development and use of consequences tables is critical to the risk assessment. Effective consequences tables have been developed by relevant experts and for each type of asset or impact under consideration (for example, infrastructure, species, habitat, tourism, heritage, and amenity) clearly describe the nature and extent of impact for each consequence level. The expert team needs to put considerable effort into alignment of consequence levels across the table. Table 5 is a public domain example of a consequences table that was developed for a major Victorian environmental effects statement (EES).

Table 5: Example of a consequence table.

CONSEQUENCE LEVEL		NEGLIGIBLE	MINOR	MODERATE	MAJOR	HIGH
		Minimal, if any impact for some communities. Potentially some impact for a small number of (<10 individuals).	Low level impact for some communities, or high impact for a small number (<10) of individuals.	High level impact for some communities, or moderate impact for communities bay-wide.	High level of impact for communities bay-wide.	High level of impact State-wide.
Property/infrastructure		0.1	1	10	100	1000
	Cost to repair/replace (and lost revenues)	Approximate range from \$0 to \$0.1 million.	Approximate range from \$0.1 to \$1 million.	Approximate range from \$1 to \$10 million.	Approximate range from \$10 million to \$100 million.	Approximate range from \$100 million to \$1 billion.
Environmental	Ecosystem Function (need to consider resilience and resistance)	Alteration or disturbance to ecosystem within natural variability. Ecosystem interactions may have changed but it is unlikely that there would be any detectable change outside natural variation or occurrence.	Measurable changes to the ecosystem components without a major change in function (no loss of components or introduction of new species that affects ecosystem function). Recovery in less than 1 year.	Measurable changes to the ecosystem components without a major change in function (not loss of components or introduction of new species that affects ecosystem function). Recovery in 1 to 2 years following completion of Project construction.	Measurable changes to the ecosystem components with a major change in function. Recovery (ie within historic natural variability) in 3 to 10 years following completion of Project Construction.	Long term and possibly irreversible damage to one or more ecosystem functions. Recovery, if at all, greater than 10 years following completion of Project Construction.
	Habitat, communities and/or assemblages	Alteration or disturbance to habitat within natural variability. Less than 1% of the area of habitat affected or removed.	1 to 5% of the area of habitat affected in a major way or removed. Reestablishment in less than 1 year (relative to component seasonality) following completion of Project construction.	5 to 30% of the area of habitat affected in a major way or removed. Reestablishment in 1 to 2 years following completion of Project construction.	3 to 90% of the area of habitat affected in a major way or removed. Reestablishment in 3 to 10 years following completion of Project construction.	Greater than 90% of the area of habitat affected in a major way or removed. Reestablishment, if at all, greater than 10 years following completion of Project construction.
	Species and/or groups of species (including protected species)	Population size or behaviour may have changed but it is unlikely that there would be any detectable change outside natural variation/occurrence.	Detectable change to population size and/or behaviour, with no detectable impact on population viability (recruitment, breeding, recovery) or dynamics. Recovery in less than 1 year (relative to species lifecycle) following completion of Project Construction.	Detectable change to population size and/or behaviour, with no detectable impact on population viability (recruitment, breeding, recovery) or dynamics. Recovery in 1 to 2 years following completion of Project Construction.	Detectable change to population size and/or behaviour, with no detectable impact on population viability, or dynamics. Recovery (ie within historic natural variability) in 3 to 10 years following completion of Project Construction.	Local extinctions are imminent/immediate or population no longer viable. Recovery, if at all, greater than 10 years following completion of Project Construction.
	Amenity - Recreation (water sports, fishing, beach going)	Short term interruptions in recreational use say 1 to 2 days.	Activities restricted in a localised area for short term periods (months).	Restriction on whole or parts of communities to pursue personal recreational pursuits when visiting the Bay during capital dredging period. No impact post construction period.	Long term inability for whole communities to pursue personal recreational pursuits when visiting the Bay post construction period (i.e. >2 years).	Long term inability for the general community to pursue personal recreational pursuits when visiting the Bay post-construction period for more than 10 years.
Social	Amenity - Sensory/ Perception (visual, noise, odour)	Short term impacts on Bay that alter perception as a high amenity place to live/visit. Region still seen as attractive place to live.	Short term (months) localised impacts on Bay that alter perception as a high amenity place to live/visit. Region not widely seen as attractive place to live.	Medium term (1-2 years) regional impacts on Bay that alter perception as a high amenity place to live/visit. Region not widely seen as attractive place to live.	Community perception that the Bay is significantly damaged. Bayside area loses appeal as residential area. Recover > 2 years.	Community perception that the Bay has experienced major damage as a residential location and a recreational area and is a place to be avoided. Recovery, if at all, is greater than 10 years.

	Non-Aboriginal Heritage	No measurable alterations to existing natural and human processes already impacting on heritage sites.	<p>Detectable impact to State or Commonwealth significant site with heritage values remaining largely intact.</p> <p>OR</p> <p>Partial reduction in heritage value intrinsic to non-State/Commonwealth significant site.</p>	<p>Partial reduction in heritage value intrinsic to non-State/Commonwealth significant site.</p> <p>OR</p> <p>Substantial reduction in heritage value intrinsic to non-State/Commonwealth significant site.</p>	<p>Substantial reduction in heritage value intrinsic to non-State/Commonwealth significant site.</p> <p>OR</p> <p>Complete loss of heritage value intrinsic to non-State/Commonwealth significant site.</p>	<p>Complete loss of heritage value intrinsic to State or Commonwealth significant site.</p>
	Aboriginal Heritage*	No measurable change in existing natural or human processes impacting on Indigenous Heritage Sites in any CDP Project Area.	<p>Partial removal of one or more Indigenous archaeological sites on a specific landform within a single CDP Project Area.</p>	<p>Complete removal of one or more Indigenous archaeological sites on a specific landform within a single CDP Project Area.</p>	<p>Complete or partial removal of multiple Indigenous archaeological sites on all landforms across Port Phillip Bay.</p>	<p>Complete or partial removal of multiple Indigenous archaeological sites on all landforms across Port Phillip Bay.</p>
Economic	Commercial fishing and aquaculture	Limited or short term reduction in activity. Limited impacts localised and not Bay wide. No significant impact on regional businesses.	Short term reduction in activity in less than one year.	Significant reduction (5-30%) in fishery capacity. Recovery in 2 to 10 years.	Permanent significant reduction (30-90%) in sustainable yield of the fishery and/or aquaculture industry. Impact Bay wide.	Commercial fishing and aquaculture completely and permanently prohibited or destroyed across the whole bay.
	Tourism	Limited and short term reduction in tourist visitation. Limited impacts localised and not Bay wide. No significant impact on tourism businesses. Region still seen as attractive place to visit.	Short term reduction in tourism use. Recovery in less than 1 year.	Substantial reduction in tourism use. Recovery in 2-10 years.	Permanent reduction in visitation with changes in character of visitors. Impact Bay wide. Business viability compromised across wide range of sectors with substantial business failure in both direct and flow on sectors. Impact noticed on Melbourne region and State tourism numbers.	Permanent loss of icon tourism assets of national significance. Significant flow on affects to supporting businesses.
	Shipping	Shipping disruption of negligible consequence. Shipping disrupted for 1-2 hours.	Port closed for 24 hours.	Port closed for 1 week, or significant ongoing unexpected interruptions to Port business.	Port closed for 1-4 weeks.	Closure of shipping channel to all vessels. Infrastructure loss has extreme consequences. Shipping channel is not able to be opened for more than 1 month.
	Delayed project benefits			Project delayed around 1 year.	Project delayed by 1-3 years	Project delayed by more than 3 years.
Public health and safety	Minor injury/illness	Minor injury or illness to less than 10 individuals.	Minor injury or illness to between 10 and 100 individuals.	Minor injury or illness to between 100 and 1000 individuals.		
	Major injury/illness	Major injury or illness to 1 individual.	Major injury or illness to between 1 and 10 individuals.	Major injury or illness to between 10 and 100 individuals.	Major injury or illness to between 100 and 1000 individuals.	
	Fatality/serious injury, disability		1 fatality or serious injury		Between 1 and 10 fatalities or serious injuries.	Greater than 10 fatalities or serious injuries.

Consequence tables can be very useful for environmental impact statement risk assessments where the risks to diverse environmental and social assets need to be communicated to the community stakeholders. Stakeholders often understand that consequence tables will never be perfect, or agreed on by everyone, but acknowledge that if well constructed, they allow useful comparison between diverse types of events. Consequently, such semi-quantitative approaches have been supported by many stakeholder groups.

However, semi-quantitative approaches share some shortcomings with qualitative approaches; that is in circumstances when it is difficult to compare events on an even basis, it is difficult to justify weightings placed on severity of consequences and the use of emotive labels.

6.4 Quantitative methods

Quantitative risk assessment is increasingly applied in the mining and minerals industry due to business requirements to support financial decisions; evenly compare financial risks with environmental and social risks; and to demonstrate transparency, consistency and logic of approach. However, quantitative risk approaches often are not intuitive and require some up-front learning investment by decision makers.

Quantitative risk assessment is used across the full range of risk applications—from deriving preliminary, first-pass separation of risk events to much more comprehensive assessments. The comprehensive assessments can derive detailed risk profiles for priority ranking, estimates of the costs that may be incurred due to risk events, input to financial models, and a basis for cost-benefit analysis.

Quantitative risk assessment follows the basic risk assessment approach (of deriving an expression of risk, termed the risk quotient, from the product of likelihood and consequences) to its full extent by attributing absolute values to likelihood and consequences.

Estimates of likelihood are made in terms of event frequency (for example, annual frequency or frequency over the period of a specified project) and/or probability of occurrence of the risk event.

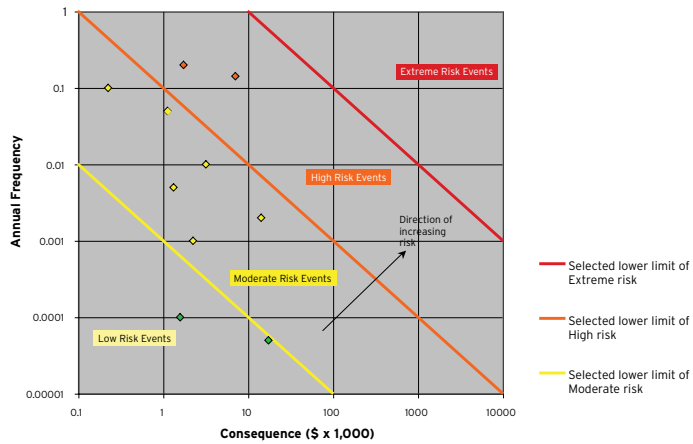
Estimates of consequence can be made using any consistent measure, selected according to the nature of the application. For example, dams engineering risk assessments often measure risk in terms of frequency and possible number of lives lost, while financial controllers may measure risk in terms of frequency and cost (expressed in monetary terms).

The risk quotient is used to differentiate, on a comparative basis, between risk events using a consistent measure of risk and to identify those events that pose the most risk. Where consequences are expressed in financial terms, the risk quotient is equivalent to the commonly used term 'expected cost' or 'expected value'.

6.4.1 Risk maps

A risk map is the quantitative equivalent to risk matrices that are typical outputs from qualitative and semi-quantitative risk assessments. Figure 6 shows an example risk map that was derived using the same knowledge base as the more qualitative examples above.

Figure 6: Example of a risk map.



Source: Adrian Bowden

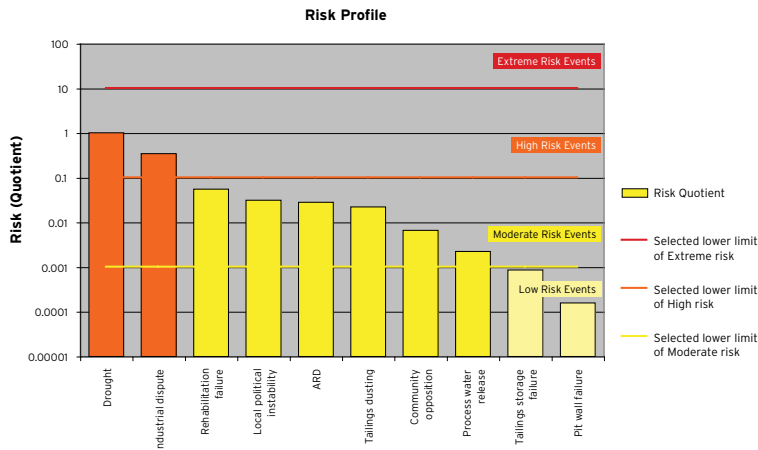
Like a risk matrix, the risk map shows the relationship between likelihood (vertical axis) and consequence level (horizontal axis) for each event, and also shows how the events can be rated from low to extreme risk if desired.

The risk map construction recognises that the scales of both likelihood and consequence of risk events are perceived to differ by orders of magnitude. Consequently, the diagonal lines represent lines of equal risk. The line showing 'selected lower limit of extreme risk' shows that the risk quotient (calculated as likelihood x consequence) is equal to 10 at all intersection points along the line. For example, points (100, 0.1), (1000, 0.01), (10 000, 0.001) all show equal risk. In addition, any events with risk quotients greater than 10 would plot above the selected lower limit and would be considered to pose extreme risk.

6.4.2 Risk profiles

Risk profiles are more commonly used to express the basic outputs of quantitative risk analysis. Figure 7 shows an example of a risk profile generated from the same data as the risk map above.

Figure 7: Example of a risk profile.



Source: Adrian Bowden

The risk quotient for each potential event is shown on the vertical axis and is calculated from the product of the likelihood of occurrence and the cost if the event occurred. The selected lower limits of each risk rating are also indicated on the profile.

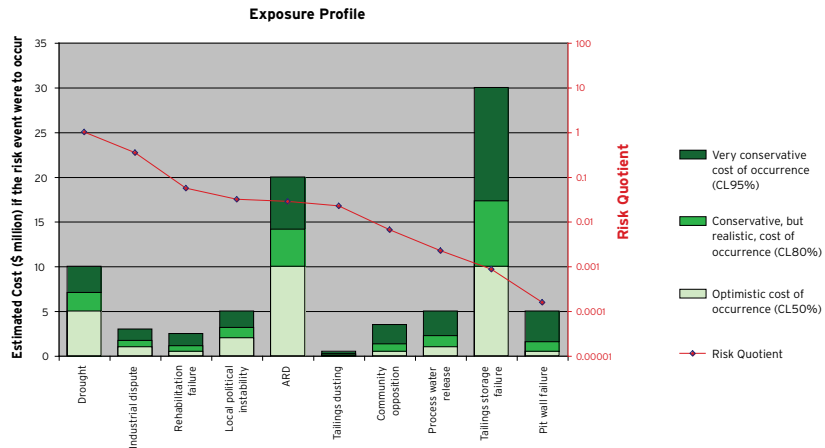
Figure 7 shows that the risk quotients of all events are directly comparable. For example, the first event presents more than 10 times more risk than the third risk event. In this example, the events in Figure 7 are ranked in order of decreasing risk which assists with prioritisation of events as part of the risk management process.

Additional profiles can be generated to assist development of appropriate risk treatment strategies. Exposure profiles (like Figure 8) that show the estimated cost of risk issues clearly indicate both the risk of each event and the potential financial exposure if the event were to occur. Identification of a high-risk, high-cost event, for example, would indicate that priority action should be carried out to address the risk.

Uncertainty associated with quantifying consequences has been incorporated into the example calculations using off-the-shelf Monte Carlo simulation software (for example, @RISK, Risk Solver, Risk AMP, Crystal Ball) to input costs as probability distributions rather than as a single value.

On the exposure profile of Figure 8 the differences between the costs at the selected confidence levels that were obtained from the Monte Carlo simulation show the range of uncertainty associated with the consequences of each risk event. This characteristic is often used to decide whether immediate action would be most appropriate or whether an event should be further studied to increase knowledge of the issue (and reduce the uncertainty) prior to taking action.

Figure 8: Example of an exposure profile.



Source: Adrian Bowden

Additional outputs of quantitative risk assessment that are used to develop and support risk management strategies show profiles of event likelihoods and cost-benefit relationships (progressive costs to implement a risk management strategy versus reduction in risk or reduction in the estimated future cost of risk events).

Fully quantitative risk assessment is not very useful for environmental impact study type risk assessments, where there are many diverse environmental and social issues that need to be evaluated, and their risk communicated to the community and other stakeholders. People often do not accept the concept of placing a dollar value on 'intangible' and often emotive events.

Quantitative risk assessments need to be carefully designed and implemented, and address many of the drawbacks associated with more qualitative approaches.

Quantitative risk assessment is very useful for development and justification of comprehensive risk treatment strategies and for internal business decisions that involve complex business risk events and a wide range of environmental and social issues. In such cases the results can be readily expressed in financial terms and incorporated into the business planning process.

Successful application of quantitative risk assessment is however dependent on the availability of necessary data, and the capacity and commitment of the organisation to manage the process and to source the required expertise.

6.5 Periodic reviews

Risk assessment is not a one-off process. Regular review of risk assessment outcomes is required for a range of reasons:

- to check the effectiveness of risk controls (see Chapter 7);
- to redefine the context and better define the scope of risk assessments (see Chapter 5);
- to capture new risks or remove risks that are no longer relevant to the organisation (changing risk profile); and
- to refine the outcomes of the risk assessment process by involving different people and by applying a broader range of experience to the assessment process.

6.6 Conclusions

A wide range of risk assessment approaches are available to the mining industry. It is important that decision makers choose a risk assessment technique that is suited to their application and information needs, and that it is an informed choice based on an understanding of the relative strengths and weaknesses of these risk assessment methodologies.

Decision makers who will use and rely upon the results of a business risk assessment must be comfortable with the process used, in order to have confidence and trust in the findings.

The selection of the most appropriate risk analysis method for a given application will depend on the aims of the risk assessment, the nature of the risk events, existing organisational preference, and investment in risk management processes and systems

Qualitative, semi-quantitative and quantitative risk assessment can be used to generate quick, first-pass assessments of risk. In general, the more sophisticated the risk assessment technique used, the more detailed the information will be that is produced from the assessment process. Traditionally, assessment of social and environmental business risks has been somewhat limited by the constraints of qualitative and semi-quantitative techniques but, over time, new quantitative risk assessment tools have been developed to overcome some of the shortcomings of these methods.



7.0 RISK CONTROLS

Purpose

The purpose of this section is to discuss the importance of risk control design and ensuring appropriate action is taken to deal with significant risks that have been identified.

KEY MESSAGES

- The most important part of the risk management process is to take action to manage significant risks and to capitalise on opportunities.
 - Risk control design aims to ensure the reliability of a risk control, given the potential consequences associated with the risk. As the consequences increase, there is a need to have a greater degree of confidence that the control of the risk will be effective.
 - For existing operations, risk controls are generally described as being engineering, system, procedural or people-based.
 - Effective execution of controls generally requires designation of a control owner, performance monitoring, and reporting of the control performance.
 - The responsibilities of control owners of critical controls should be documented either in their position description or in the procedure or system design document from which the control is derived. Critical controls can be included as an element in the control owner's personal performance scorecard.
 - Performance monitoring and reporting of a key control ensures that the control remains effective and performance shortfalls are identified promptly.
 - A defined critical equipment management program is an effective means of managing the risks associated with equipment failure.
 - Emergency response, crisis management and business continuity plans and capabilities are valid and important elements of mitigating controls for operational risks.
 - In addition to routine performance monitoring, key risks with potentially material consequences should also undergo periodic independent assurance assessment and reporting.
-

7.1 Introduction

The ultimate objective of risk management is to avoid the impacts of unplanned events or to successfully capture the benefits of an opportunity. Inherent in this objective is the need to effectively manage key risks. Risk treatment is the term used to describe the approach taken to manage a risk.

Inherent in most approaches to risk treatment is the need to appropriately design and effectively execute risk controls.

A risk control is a system, process, procedure, equipment or other organisational capacity that prevents the consequences of the threat from occurring. Controls can be preventive, detective, protective or mitigating.

Preventive controls are aimed at preventing the unwanted events from occurring. Detective controls detect the unwanted event as it is occurring. Protective controls are designed to reduce the immediate impacts. Mitigating controls are designed to reduce the long-term impacts of the unplanned event through prompt recovery to an acceptable state.

7.2 Risk control design

Risk control design is aimed at ensuring that the reliability of a risk control is appropriate given the potential consequences associated with the risk. As the consequences increase, there is a need to have a greater degree of confidence that the risk control will be effective.

- Potential approaches to risk treatment include:
- eliminate or reduce the risk—modify the process or improve controls to either reduce the likelihood of the risk eventuating or reduce the consequences;
- manage the risk—use existing controls;
- manage and monitor—use existing controls but include processes to monitor the ongoing efficacy of the controls; and
- transfer the risk—use insurance or joint-venture arrangements to have a third-party share the potential consequences of the risk.

When designing a new system or facility, the traditional hierarchy of controls can be used to maximise the effectiveness of controls.

Hierarchy of controls

1. Eliminate the risk
2. Minimise or replace the risk
3. Control the risk using engineered devices
4. Control the risk by using physical barriers
5. Control the risk with procedures
6. Control the risk with personal protective equipment
7. Control the risk with warnings and raising awareness.

Adapted from: NSW Department of Primary Industries (2007).

In existing operations, risk controls are generally described as being engineering, system, procedural or people-based.

Engineering controls are inherent in the physical design of plant or equipment. Engineering controls are 'automatic' and do not require human intervention to be effective. Control reliability is achieved by having an adequate margin between the critical engineering characteristic of the control device and the system's potential range of variability.

System-based controls are executed automatically or by people within the bounds of a defined management system. Execution is based on a prescribed approach governed by system-set rules and protocols. Control reliability is achieved through the system surrounding the control, including management review and follow up.

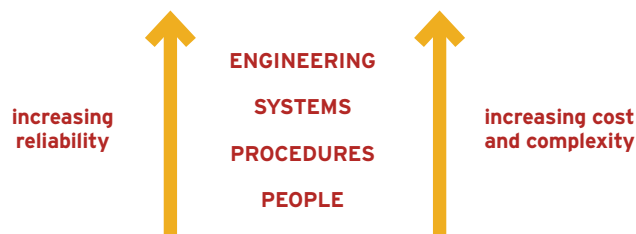
Procedural-based controls are executed by people according to a written set of rules or guidelines. Control reliability is achieved through the effective design of the procedure, through the training and competency of people required to execute the procedure, and through monitoring of performance.

People-based controls rely entirely on the skills, knowledge and experience of individuals to identify a hazardous situation, assess the potential consequences and to react accordingly. Control reliability is achieved by the inherent experience and capability of the people.

There can be overlap between these characteristics and existing controls. A specific control may, for example, have some characteristics of a procedural control and some elements of a system-based control.

Engineering or system-based controls are more reliable than procedural or people-based controls. However, engineering or system-based controls are, generally, more expensive or difficult to implement than procedural or people-based controls.

Figure 9: Types of risk control.



Source: Martin Webb (BHP Billiton)

Increasing confidence in risk management is achieved by applying high-reliability controls to risks with high-potential consequences.

Risk tolerability can be established by setting the minimum type of control for a given severity of potential consequences.

Whether engineering, system, procedural or people-based, controls for material risks should have documented control objectives and related performance targets.

The control objective is a statement of the target outcome of the control. The performance target usually specifies the required level of repeatability of the control or, conversely, to the maximum allowable 'failure-on-demand' for the control. These elements provide the basis by which the ongoing effectiveness of the control can be assessed.

7.3 Risk control execution

Effective execution of controls generally requires designation of a control owner, performance monitoring and reporting of the control performance. There should also be a system in place to ensure that performance improvement efforts are undertaken when measured control performance for a critical control falls below its minimum performance requirements.

The control owner has responsibility for ensuring effective and consistent performance of the control. The responsibilities of control owners of critical controls should be documented either in their position description or in the procedure or system design document from which the control is derived. For critical controls, the performance of the control can be included as an element in the control owner's personal performance scorecard.

Performance monitoring and reporting of a key control ensures that the control remains effective and that performance shortfalls are identified promptly. Performance monitoring of critical controls should be routine rather than ad hoc. The frequency of monitoring and reporting should depend on the criticality of the control.

Critical equipment management

A defined critical equipment management program is an effective means of managing the risks associated with equipment failure.

An effective critical equipment management program includes:

- clear definition of 'critical equipment' based on the potential impacts of equipment failure;
- a systematic process for identifying critical equipment that includes technical experts and stakeholders a 'critical equipment register' that contains details of critical equipment including:
 - the make and model of the equipment;
 - the equipment's purpose and performance requirements;
 - details of the potential consequences associated with equipment failure;
 - the required testing, inspection and preventive maintenance program; and
 - testing, inspection and maintenance records.

- a maintenance work order process that differentiates work planning and completion reporting on critical equipment (against non-critical equipment);
- management reporting on completion of critical equipment testing and maintenance;
- a critical equipment disablement or bypass approval procedure; and
- workforce training.

7.4 Emergency response, crisis management and business continuity plans

Emergency response, crisis management and business continuity plans and capabilities are valid and important elements of mitigating controls for operational risks.

Emergency response includes the fixed and mobile equipment and human capacity needed to minimise the physical impacts of an event. Fire fighting and mines rescue are typical emergency response capabilities required at an operating mine site.

Crisis management is the management structure and capacity needed to support the emergency response team and to manage the indirect consequences of the emergency.

Business continuity is the management structures and pre-investment in capacity and other arrangements designed to minimise the period that business is interrupted by the emergency.

As with other mitigating controls, there needs to be clear control objectives and performance targets for emergency response, crisis management and business continuity plans and capabilities. The plans and capabilities should also be tested against their respective key performance indicators.

Where required to mitigate substantial operational risks, respective emergency response, crisis management or business continuity plans should be referenced in the asset's risk register.

7.5 Control assurance

In addition to routine performance monitoring, key risks with potentially material consequences should also undergo periodic independent assurance assessment and reporting.

Assurance is the explicit, systematic and objective examination of evidence for the purpose of providing an independent assessment of the efficacy of risk management processes and controls against established performance criteria. The scope should include the design and performance of the processes and controls.

Control assurance reviews should be led by a person with no direct responsibility for either the design or the execution of the control, but should include the control owner and other key stakeholders. Control assurance reports for critical controls should be reviewed and endorsed by the asset management team. Accountability for completing agreed control improvement plans should be assigned to an individual and progress on the plan should be tracked by management through to completion.



8.0 RISK COMMUNICATION

Purpose

This section highlights the importance of risk communication within the organisation and externally, and outlines the key concepts and methods.

KEY MESSAGES

- Risk communication is the deliberate exchange of information about the nature, severity, or acceptability of risks and the decisions taken to combat them.
- Mining companies have a responsibility to effectively communicate knowledge of significant risks to employees and the public, as well as facilitate stakeholder engagement processes that contribute to the understanding of the risks from broader stakeholder perspectives.
- For complex risk situations involving a range of community stakeholders, risk communication steps will need to be worked through systematically for effective risk management outcomes.

8.1 What is risk communication?

Effective risk communication is a key part of the strategy to build community trust, improve understanding within the community in relation to mining and mineral processing-related risks, and for industry to better understand the views of stakeholders who may be impacted by mining or mineral processing activities. The risk communication process must be two-way to be meaningful; that is, it should involve as much listening as talking, with clear evidence of responsive action based on this interaction.

A comprehensive definition of risk communication is provided by the Department of Health and Ageing and enHealth Council (2002 p. xvi):

“Risk communication is the deliberate exchange of information about the nature, severity, or acceptability of risks and the decisions taken to combat them. Risk communication should be seen as a process that enables all stakeholders to make an informed judgment about a risk and its management. The process must involve a frank and open presentation of all relevant background information to the stakeholders, in a manner understandable by all. This process also involves listening to stakeholders.”

The enHealth Council defines three perspectives to risk: actual, estimated and perceived. "The estimated risk is the outcome of the risk assessment with its uncertainties. The actual level may never be known because there may not be instruments available to 'measure' it or because actions will change the course of events. All stakeholders will have their own perceptions of the risk. Good risk assessment and risk communication minimise the mismatch between these three perspectives of risk and assist in efficient risk management" (enHealth Council 2002).

It is important to emphasise the value of two-way communication; that is, the mining company has a responsibility to effectively communicate its knowledge of significant risks to employees and the public, as well as facilitate stakeholder engagement processes that contribute to the mining company's understanding of the risks from broader stakeholder perspectives. In this way the mining company is better able to adapt and respond to community expectations.

Mining companies therefore need to consider the legitimate views held by members of the community, the policies and interests of government agencies, the expertise of academics and independent consultants, and the views of NGOs advocating improvements to community and environmental health. There is often collective wisdom in these various groups which can provide important insights into assessing, managing and communicating various risks.

8.2 Principles of risk communication

A set of principles that are relevant to proactive risk communication are presented below for application by the Australian minerals industry. A different and more specific set of risk communication principles should be applied for crisis situations where a significant incident has triggered a rapid response requirement.

The following principles and elements have been compiled as a synthesis of principles from a range of sources.

Risk communication principles

The following general risk communication principles are proposed for the Australian minerals industry:

Honesty

Be objective, not subjective. Do what was promised and do it on time. Not obeying this rule greatly jeopardises an organisation's trustworthiness.

Unrealistic expectations can be avoided with honest and candid public accounting of what is and is not known, and what can and cannot be done. Promise no more than can be delivered.

Trust and credibility are difficult to obtain; once lost, they are almost impossible to regain.

Proactive

The proactive approach is effective.

Being proactive means not waiting for problems to surface, having a structured communication system in place, and building up trust before it is needed.

Cultural differences

Cultural and gender diversity should be taken into account. For example, communication of risk to Indigenous communities should take account of their specific rights, interests and methods of communication.

What works in one place does not necessarily work in another place. Involving and working with local people, who are familiar with the local customs, is a wise strategy. Experts may need to be engaged to advise on intercultural issues.

Listening and engaging

Listen to the public's specific concerns, treat people with respect, involve them and take them seriously.

People often care more about trust, credibility, competence, fairness and empathy than about statistics and details.

Dealing with emotions

Emotions come into play, as environmental health often affects what people care about, such as their personal health, the health of their loved ones, and the value of their property. Addressing technical issues alone is a strategy that almost always fails.

Consistency and clarity of message

Convey the same information to all stakeholder groups (for example, employees, local community, government). This does not mean the same communication approach should be used, but the message must be consistent.

Simplify language and presentation, not content or messages.

Timing of communication

Communicate early, often and fully.

With the continuing evolution in modern communications technology, it is critical to ensure that all appropriate avenues of communication are utilised effectively and in a regular, timely fashion. This helps to maintain and build transparency and trust.

Multiple perspectives

Understand that different stakeholders will have different perspectives and accept that these differing views are valid. Remember that perception is reality.

People's tolerance to risk is dependent on their values or beliefs, as well as their capacity to understand scientific information. For example, ignoring moral positions on a risk while adopting a technocratic stance will invariably increase tension and lose respect and trust. It is important to legitimise different perspectives held by different stakeholders, and ensure the risk communication process includes this philosophy.

Know your audience

Identify the various stakeholders who have an interest in the risk situation. Develop an understanding of their motives, level of interest and likely perspectives on the risk issue.

Flexibility

Be flexible and open to new knowledge and understanding.

Don't be limited to one form of communication. Different goals, audiences, and media require different actions.

Evaluate effectiveness of communication processes at the beginning and throughout the risk communication process.

Compassion

Speak clearly and with compassion. Always acknowledge the tragedy of an illness, injury, or death. Although people can understand risk information, they may not agree and some people will not be satisfied.

Uncertainty

Be cautious in the face of uncertainty ('better safe than sorry'). Adopt a cautious approach when faced with a potentially serious risk, even if the evidence is uncertain. This is a key principle of sustainability, commonly known as the 'Precautionary Principle'.

Credibility of message

Impose no more risk than you would tolerate yourself.

Work with other credible sources. Conflicts and disagreements among organisations make communication with the public much more difficult.

Source: adapted from a range of sources: Jardine et al. 2003, US EPA, Lundgren and McMakin 2004, Sandman 1993, Network for Industrially Contaminated Land in Europe 2004, NSW Government 2004, *Enduring Value*—Implementation Guidance 2004.

Principles for crisis communication differ from principles for proactive risk communication. Guiding principles for crisis communication are outlined in APELL for Mining (United Nations Environment Programme: 2001) and based on the European Chemical Industry Council's *Responsible Care Guidelines* the:

- successful crisis communications start with open communications with all target audiences;
- public acceptance depends on corporate behaviour before, during and after the crisis, not purely on the nature of the crisis;
- the only consistent element in all crises is the media attention;
- prepare a 'worst case' scenario;
- ignoring an issue is inviting a crisis—preparation is the only way to handle the unpredictable;
- take control of the situation and be the main source of information;
- the manner in which the first 24 hours of a crisis are handled is the most crucial;
- don't get involved in speculations on reasons and responsibilities; and
- show concern to all groups involved.

8.3 Risk communication process

To be truly proactive, organisations must have well-established risk management processes in place that identify, analyse, evaluate and treat risks. For cases where significant risks are identified, it is necessary to consider what communications are required for effective risk management. These communications could range from a simple team meeting with workers—to highlight a hazard in the workplace and discuss how to manage it—to the development of a risk communication strategy aimed at engaging with a large number of internal and external stakeholders interested in a public health risk associated with the organisation under scrutiny.

The Risk Management Standard AS/NZS 4360:2004 requires communication and consultation with internal and external stakeholders as appropriate at each stage of the risk management process and the process as a whole.

The guidelines provided in the companion to AS/NZS 4360:2004 discuss communication and consultation as important considerations at each step of the risk management process and emphasise the value of:

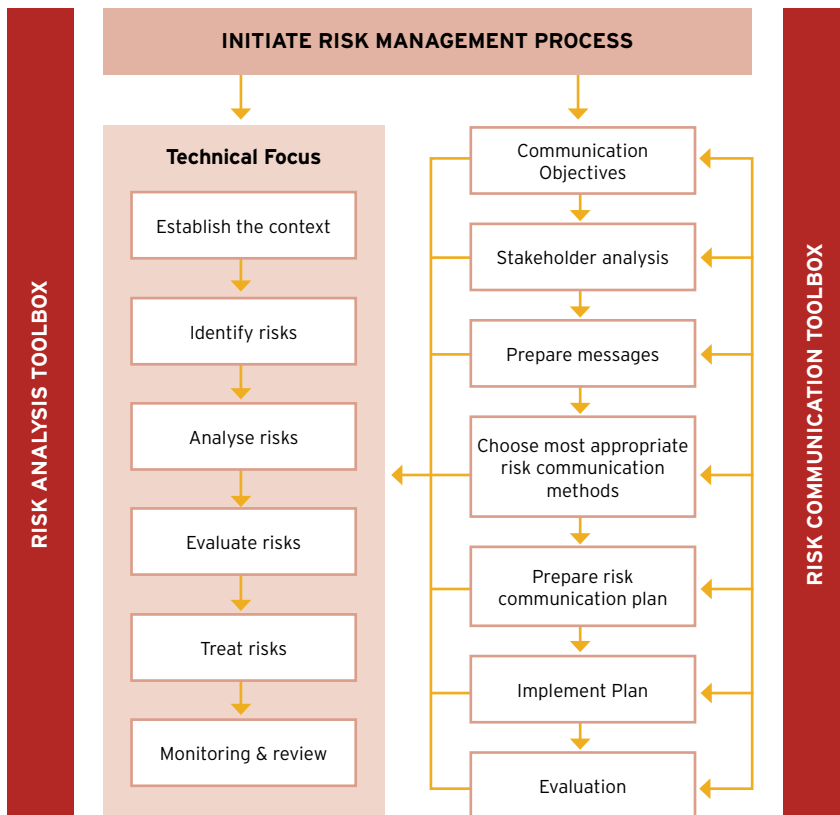
- establishing a dialogue with stakeholders with efforts focused on consultation rather than a one way flow of information;
- developing a communication plan for both internal and external stakeholders at the earliest stage in the process;
- ensuring stakeholder perceptions of risk are identified, recorded and integrated into the decision making process;

- establishing a consultative team approach to help define the context appropriately, to help ensure risks are identified effectively, bring different areas of expertise together, and ensure different views are appropriately considered; and
- involvement which allows ownership of risk by managers and engagement by stakeholders (Standards Australia: 2004b).

These important communication aspects go hand-in-hand with the outcomes of technical and overall risk evaluations (such as significance of exposures to emissions) to provide a comprehensive risk management process.

The seven communication steps outlined in Figure 10 are generic to all risk communication approaches. For simple risk situations, the steps are usually intuitive. For more complex risk situations, the steps will need to be worked through systematically, with more rigour and over longer timeframes for effective risk communication outcomes.

Figure 10: Framework and steps for risk communication in the context of risk management.



Source: Minerals Council of Australia

For example, a facility inspection might identify possible worker exposure to a hazardous chemical substance used in the process or being emitted from a mineral processing facility. Communication objectives are clear: to ensure health and safety of workers who could be exposed. The stakeholders in this case are the workers themselves, their families and the people within the organisation who need to understand the risk situation well enough to be able to take effective action. Other stakeholders may include government officers, technical or medical specialists, and local media. The communication messages will focus on what measures need to be taken to ensure the risk is managed effectively. This may involve communication on the wearing of personnel protective equipment, personnel exclusion zones, appropriate signage in the work area or communication to stakeholders on how the risk is to be engineered out of the process altogether. Once actions have been taken, the effectiveness of risk management processes need to be evaluated, including the effectiveness of communications.

For a more complex risk situation where facility emissions have the potential to affect the health of people living in adjacent communities or even further afield, it is likely that there will be a broader range of stakeholders who will have an interest, including the whole community, politicians, media, senior government officials and NGO representatives. In such cases, there are a wide range of communication approaches that may apply; however, an overarching risk management framework and risk communication principles are likely to apply in all cases.

When designing a risk communication plan, a key consideration is the level of stakeholder participation. The required level of stakeholder participation depends to a large extent on the risk situation: the assessment of hazard and the possible level of outrage based on risk perception by stakeholders. The ladder of public participation is a useful continuum to consider when making decisions on the risk communication approach to be taken. Some community engagement models use this continuum as a framework for assisting the selection of the engagement approach to be used—see the iPlan community engagement website (NSW Government 2004).

Table 6: Ladder of public participation.

LEVEL OF STAKEHOLDER PARTICIPATION	LEVEL OF POWER SHARING
Delegation/empowerment	Pass on power to other parties
Negotiation/collaboration	Share decision making
Consult meaningfully	Two-way communication, but retain decision-making control
Consult proforma	Provide opportunity for response
Inform early	Inform what is going to be done
Inform late	Inform during or after action taken
Act secretly	Intention not to inform

Source: Sandman, 1995, p. 1

8.4 Collaborative risk communication

Collaborative risk communication activities may be required between mining companies and other industrial emitters where they simultaneously contribute to the local or regional emissions. In these situations, potential exposures and consequent risks may be managed through an industry coordinating body or via government-initiated communication processes. This is a particularly complex area.

Some mining operations are also challenged by issues that are clearly historical and not a consequence of their own activities. Companies in joint ventures may encounter difficulties when their standards for risk management differ from those of partner companies.

In these situations, collaborative approaches provide opportunities for mining companies to learn from each other and this results in benefits to the industry as a whole.

8.5 Toolkit

A wide range of risk communication tools are available to industry in the form of software tools, online manuals, materials for developing risk communications plans/strategies and guidance documents.

Some tools have been developed specifically for industry; however there are many other tools and guidance documents that have been developed for government agencies, media personnel, NGOs and community groups.

The Department of Resources, Energy and Tourism's series outlines many of these tools. For further information or to obtain any of the handbooks in the series, please contact the department.



9.0 CONCLUSION

This handbook has presented key risk concepts, processes and practices that are commonly applied within the Australian minerals industry. The key messages highlighted throughout the handbook and illustrated in the case studies are:

Risk and sustainability

- The challenge of sustainable development requires the minerals industry to adopt proactive risk management approaches that recognise, integrate and implement the three pillars of social, environmental and economic sustainability.
- Risk management for mining needs to recognise uncertainty and unpredictability, fill key information gaps to reduce uncertainty and work with all relevant stakeholders in the practical implementation of the Precautionary Principle.

Types of business risk

- Mining and mineral processing operations face many types of risks including workplace health and safety, environmental, community health, regulatory, production, reputation and financial risk.
- An enterprise-wide risk framework provides guidance for a systematic, rigorous, integrated, and consistent risk management process to be implemented organisation wide, so that material risks can be identified, communicated and acted on at appropriate levels within an organisation.

Risk management process

- The main elements of risk management, as outlined in AS/NZS 4360:2004, are: (1) communicate and consult, (2) establish the context, (3) identify risks, (4) analyse risks, (5) evaluate risks, (6) treat risks, (7) monitor and review.
- Mining and processing project risks must be identified and managed at all stages of a mine life cycle.

Identifying an defining risk

- Setting the context of a risk assessment establishes the background to the risk management process, the nature of the activities and the range of potential impacts.
- A clear understanding of risk and the factors that contribute to risk is required in order to identify and describe risk, and analyse its potential impact on the environment, an organisation or an activity.

Risk assessment and analysis

- A wide range of risk assessment approaches are available to the mining industry. It is important that decision makers choose a risk assessment technique that is suited to their application and information needs.
- Qualitative risk assessment techniques use descriptive terms to define the likelihoods and consequences of risk events. The methods are quick and relatively easy-to-use, and they can provide a general understanding of comparative risk between risk events.
- Semi-quantitative risk assessment takes the qualitative approach a step further by attributing values or multipliers to the likelihood and consequence groupings.
- Quantitative risk assessment is being increasingly applied in the mining and minerals industry due to increasing business requirements to support financial decisions; evenly compare financial risks with environmental and social risks; and to demonstrate transparency, consistency and logic of approach.

Risk control

- The most important part of the risk management process is to take action to eliminate or manage significant risks.
- Risk control design aims to ensure the reliability of a risk control, given the potential consequences associated with the risk. As the consequences increase, there is a need to have a greater degree of confidence that the control of the risk will be effective.
- Effective execution of controls generally requires designation of a control owner, performance monitoring and reporting of the control performance.

Risk communication

- Risk communication is the deliberate exchange of information about the nature, severity, or acceptability of risks, and the decisions taken to combat them.
- Mining companies have a responsibility to effectively communicate knowledge of significant risks to employees and the public, as well as facilitate stakeholder engagement processes that contribute to the understanding of the risks from broader stakeholder perspectives.

GLOSSARY

Acts of God	'Acts of God' are natural events, not preventable by any human action, such as flood, storms, or lightning. They are forces of nature that a carrier has no control over and, therefore, cannot be held accountable.
AS/NZS 4360 Risk Management Standard	The Australian and New Zealand 4360 Risk Management Standard is a generic framework for establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk.
Community engagement	Deliberate and strategic liaison with communities and individuals that reside in close proximity to, and are potentially affected by, mining activity. Effective engagement typically involves identifying and prioritising stakeholders, conducting dialogue to understand their interest in a an issue and any concerns they may have, exploring with them ways to address these issues, and providing feedback on actions taken.
Control owner	The person in an organisation responsible for assuring appropriate levels of control are implemented and operated effectively for a key risk area.
Enduring Value	Enduring Value is the Australian Minerals Industry Framework for Sustainable Development. Established by the Minerals Council of Australia, it aligns with global industry initiatives and, in particular, provides critical guidance on the International Council on Mining and Metals' (ICMM) Sustainable Development Framework Principles and their application at the operational level. For further information refer to the Minerals Council of Australia web site: www.minerals.org.au .
Enterprise-wide risk framework	The overarching risk management framework that defines the scope of risk types and the key risk management processes implemented across the whole organisation to manage risk in an holistic and systematic way.
Gradual risk	A gradual risk event occurs over a long period of time and is representative of many types of pollution of the environment. For example slow leaks from hydrocarbon containment, acid seepage or emissions to the atmosphere.
Event tree analysis	A technique used to describe the range and sequence of possible outcomes of an event.
Hazard	A hazard is a source of potential harm.

Materiality	Materiality is an expression of the relative significance or importance of a particular matter in the context of the organisation as a whole.
Materials stewardship	Materials stewardship overarches the stewardship approach since it applies to resources, processes and products and, therefore, covers the full life cycle. It describes an integrated program of actions aimed at ensuring that all materials, processes, goods and/or services that are produced, consumed and disposed along the value chain are done so in a socially and environmentally responsible manner.
Monte Carlo simulation	A method for iteratively evaluating a deterministic model using sets of random numbers as inputs. The method is often used when the model is complex, nonlinear, or involves more than just a couple uncertain parameters.
Net present value (NPV)	Net present value or NPV is a measurement used to decide whether to proceed with an investment. It is calculated by adding together all the expected benefits and subtracting all the expected costs from the investment, now and in the future. If the NPV is negative, then the investment cannot be justified by the expected returns. If the NPV is positive, then it can be justified financially.
Non-government organisations (NGOs)	A non-profit group or association organised outside institutionalised political structures to realise particular social objectives (such as environmental protection) or serve particular constituencies (such as Indigenous peoples). NGO activities range from research, information distribution, training, local organisation, and community service to legal advocacy, lobbying for legislative change, and civil disobedience. NGOs range in size from small groups within a particular community to huge membership groups with a national or international scope.
Operational risk	Operational risks are those risks that are focused on addressing aspects of an operation which may be more systemic to the mining process and the day-to-day operation of a mine.
Outrage	Outrage is anger and resentment aroused by injury or insult.
Risk	Risk is the chance of something happening that will have an impact on objectives. It is often specified in terms of an event or circumstance and the consequences that may flow from it.
Risk analysis	Risk analysis is the systematic process used to understand the nature of, and to deduce the level of, risk. It provides the basis for risk evaluation and decisions about risk treatment.

Risk control	A risk control is an existing process, policy, device, practice or other action that acts to minimise negative risk or enhance positive opportunities.
Risk criteria	Risk Criteria are the terms of reference by which the significance of a risk is assessed.
Risk evaluation	Risk evaluation is the process of comparing the level of risk against risk criteria.
Risk management	Risk management is the process and structures that are directed towards realising potential opportunities while managing adverse effects.
Risk management process	The risk management process is the systematic application of management policies and procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk.
Risk register	A risk register records the outcomes of risk identification and assessment processes in a systematic way—usually set out in a table—and defines risk scenarios, assessment outcomes, risk control actions and responsibilities.
Similar exposure group	Groups of workers having the same general exposure profile due to the similarity and frequency of the tasks they perform, the materials and processes with which they work, and the similarity of the way they perform the tasks.
Social licence to operate	The recognition and acceptance of a company's contribution to the community in which it operates, moving beyond basic legal requirements towards developing and maintaining the constructive relationships with stakeholders necessary for businesses to be sustainable. Overall it strives for relationships based on honesty and mutual respect.
Stakeholders	Stakeholders are those people and organisations who may affect, be affected by, or perceive themselves to be affected by a decision, activity or risk.
Strategic risk	Strategic risks are those risks that relate to the interdependencies between an operation's activities and the broader business environment.
Sustainable development	Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Threat	A threat is the possibility that vulnerability may be exploited to cause harm to a system, environment, or personnel.

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WEB LINKS

- Leading Practice Sustainable Development Program for the Mining Industry, www.ret.gov.au/sdmining
- Risk Assessment and Perception, zebu.uoregon.edu/1999/ph161/l20.html
- Minerals Industry Risk Management Gateway, www.mirmgate.com
- Risk World, www.riskworld.com
- The Risk Assessment Information System, rais.ornl.gov
- Minerals Industry Safety and Health Centre (UQ), www.mishc.uq.edu.au/index.html
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