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Department of Resources
Energy and Tourism

WATER MANAGEMENT

LEADING PRACTICE SUSTAINABLE DEVELOPMENT PROGRAM FOR THE MINING INDUSTRY

SOCIAL
ECONOMIC
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MAY 2008

Disclaimer

This publication has been developed by an expert working group of representatives from industry, government, research and non-government organisations. The efforts of the members of the working group are gratefully acknowledged.

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Cover image: Aerial photograph of Ranger Uranium mine in the Northern Territory. ©Energy Resources of Australia Ltd

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RioTinto	**Mr Dennis Gibson** Chair General Manager, Water Resources Rio Tinto Iron Ore	www.riotinto.com
The University Of Queensland AUSTRALIA	**Professor Chris Moran** Principal Author Director, Centre for Water in the Minerals Industry Sustainable Minerals Institute The University of Queensland	www.smi.uq.edu.au
Australian Government Department of Resources Energy and Tourism	**Ms Shelby A E Schofield** Secretariat Sustainable Mining Department of Resources, Energy & Tourism	www. ret.gov.au
CSIRO	**Dr Graeme Batley** Centre for Environmental Contaminants Research CSIRO Land and Water	www.csiro.au
Minerals Council of Australia	**Mr Jason Cummings** Assistant Director–Environmental Policy Minerals Council of Australia	www.minerals.org.au

	**Mr Mark Edebone** Group Manager–HSE Iluka Resources Ltd	www.iluka.com
	**Mr Barry Jilbert** Manager–Water Effectiveness Rio Tinto Iron Ore	www.riotinto.com
	**Dr David Jones** Director Environmental Research Institute of the Supervising Scientist	www.environment.gov.au/ssd
	**Ms Catherine Kesteven** Sustainability and Water Policy Department of Resources, Energy and Tourism,	www.ret.gov.au
	**Ms Erika Korosi** Global Practice Leader–Water BHP Billiton	www.bhpbilliton.com
	**Dr Andrew Markham** Hydrobiology Pty Ltd	www.hydrobiology.biz/
	**Mr Greg Morris** Chief Environment and Community Advisor Newcrest Mining	www.newcrest.com.au
	**Professor David Parry** Leader–Tropical Futures: Mineral Program Charles Darwin University	www.cdu.edu.au
	**Dr Ross Smith** Hydrobiology Pty Ltd	www.hydrobiology.biz/
	**Dr Jeff Taylor** Director–Principal Environmental Geochemist Earth Systems	www.earthsystems.com.au/
	**Mr Alan Wright** Environmental Hydrogeologist Metago Environmental Engineers	www.metago.com
	**Professor David Williams** Golder Professor of Geomechanics The University of Queensland	www.uq.edu.au

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FOREWORD

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

The handbooks in the *Leading Practice Sustainable Development in Mining* series integrate environmental, economic and social aspects through all phases of mineral production from exploration through construction, operation and mine-site closure. The concept of leading practice is simply the best way of doing things 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.

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

INTRODUCTION

Leading practice describes how specific management and technical issues are dealt with in the most effective manner at a particular time - it is not a term that describes a single operation. Rather, it is a collection of practices that are applied across a range of operations. It is constantly changing and evolving as operations improve the way they do things as a result of new ideas, new technologies and increased effort. It is about ongoing improvement rather than an auditable end point.

Water management is a very broad topic. Many practitioners are most familiar with the technical aspects of water management including pumps, pipes, storages and slurries. However, it is important not to overlook the social and environmental issues which effect water management.

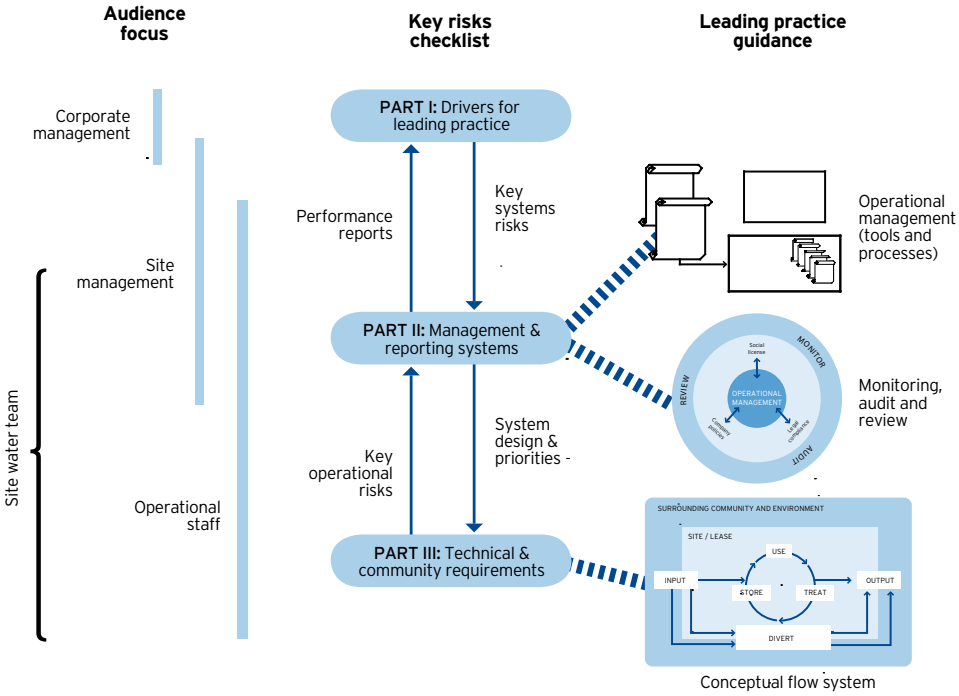
Across Australia, the water sector is experiencing wide-spread changes associated with the National Water Initiative (NWI) that will change the regulatory environment within which the mining industry will be required to operate. These changes will modernise and ensure a consistency of approach across jurisdictions. Paragraph 34 of the NWI recognises that the mining sector can face special circumstances which may require specific management arrangements that are beyond the scope of the NWI Agreement. Increasingly, mining companies in Australia are stating a commitment to principles of sustainable development. This commitment creates a range of complexities associated with managing water. These complexities can exist above a single operation and may be important across the whole of the company or even the industry in a national or global context.

It is necessary that a leading practice handbook for water management address this range of issues, covering both the technical and management processes. The integrating theme used to bring this together is risk management. The process of risk management is described in greater depth in another dedicated handbook (www.ret.gov.au/sdmining). This handbook provides guidance on the processes required to identify the risks (both technical and management) relevant to a particular operation, how these might be mitigated, and how this can be supported by the necessary monitoring and audit systems that provide confidence in reporting of activities and outcomes.

Figure 1 illustrates how these issues are addressed in this handbook. The central three boxes in the figure show the main three topics that are addressed. The icons shown on the right side of Figure 1 are key diagrams in the text and are given to help the reader navigate the structure of the handbook. The handbook is divided into three parts.

Part I deals with the drivers for leading practice and identifies potential key system risks. Part I also includes consideration of the principles—consistent with ISO1400 requirements—that should be considered when identifying and managing water-related risks.

Figure 1. The key features of leading practice around which this handbook is organised, including the focus audiences and their primary areas of interest.



Part II describes management tools and processes to assist an operation gaining assurance of their level of performance. Key components are the site water strategy, the water management plan and the operational procedures. These components support the development of appropriate water accounts which are formed by combining site data and a water circuit diagram through water balancing. Part II also provides guidance on processes for monitoring, auditing and reporting at leading practice standards.

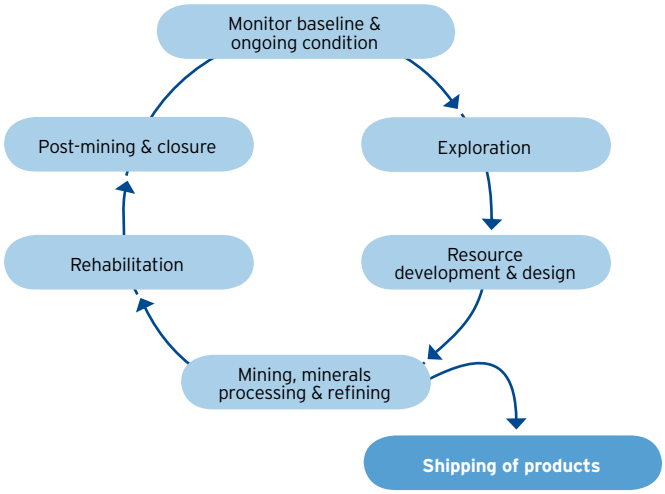
Part III of the handbook deals with the technical aspects of leading practice water management. Part III is structured using a conceptual flow system diagram which will be familiar to many water managers (Figure 1 bottom right). Issues of dealing with community and surrounding environment are outlined. The risks associated with water input, diversion, internal site water use, treatment and storage, and output from the operation are listed. These risks are supported with mitigation strategies and additional information.

SCOPE

Water must be managed at all stages of the life cycle of mining operations (Figure 2) – the scope of this handbook covers all stages, including monitoring before and after the operation. Rather than deal with every life cycle stage in every section of the handbook, issues associated with one or more life cycle stages that are critical to a particular risk are highlighted in the appropriate sections. In this way, the life cycle is embedded into the handbook's structure.

The *Stewardship* handbook (www.ret.gov.au/sdmining) also provides leading practice guidelines for considering water implications, such as up and down the supply and product lines from the operation.

Figure 2. The main operational phases in a mining operation life cycle and the main water issues in each phase. Interactions with surrounding community and environment must be actively managed at all life cycle stages.



Water management is a collective responsibility across the operation. Collective management does not mean that responsibility for particular areas cannot be assigned. Table 1 provides an overview of water-related tasks (operational uses of water) for many mining operations and some logical associations with the functional areas responsible for them. Collective responsibility is best managed through single point accountability – that is, the operation must have someone in charge of committees and processes.

The aim of the handbook is to provide a guide to operational managers on a structured approach to water management. It does not attempt to address detailed technical water management at a site operator level. A number of reference sources are available to support this, for example Younger & Robins (2002), Younger et al. (2002), the 1997 MCA *Mine site Water Management Handbook* and the Best Practice Environmental Management water book (www.ret.gov.au).

A given operation may not need to achieve leading practice in all aspects of its water management system, since to do this may demand allocation and mobilisation of resources (such as people and money) in excess of the benefit to be gained. This could potentially detract effort from management of other risk areas. Operations should select the leading practices that mitigate the risks based on their individual business case. Leading practice operations make this selection by means of a risk-based assessment of key aspects of water management (as demonstrated in the Rio Tinto diagnostic case study).

Table 1. Typical tasks and responsibilities for each of the teams managing water on mining operation. Note that there are some overlaps between groups and actual responsibilities will vary according to site dictates.

AREA	TASK
Corporate	Development of strategic water management plan. Engagement with government—approvals. Formulation of sustainable development strategy—including compliance and external reporting. Formulation and communication of company-wide strategies, processes and plans.
Mining/ operations	Managing storages, roads and drainage to meet licence regulatory requirements (not necessarily—may be environment). Development of site water management plans and balances. Water risk assessment and management. Supply/demand management. Pit and advance mining dewatering. Flood and drought management contingency plans. Dust suppression (typically roads, stockpiles and conveyors). Vehicle wash down (minor). Building and maintenance works. Closure implementation—water and tailings. Fire and potable water.
Mineral handling and processing	Separation of mineral and gangue materials. Tailings and reject management. Process water and recycling management. Dust suppression—stockpiles, conveyor and drainage of industrial area.
Environment and community	Rehabilitation planning. Closure planning. Water flow and quality monitoring. Onsite and surrounding ecosystems management. Participating in regional and local water planning. Engagement with TOs, NGOs, key stakeholders. Corporate reporting—internal and external.

The design and performance of the water management system at any given operation will be a function of the corporate, legislative, climatic and local community environments in which they operate. Water management will only improve with the personal leadership and specific mandate of executive management and the proactive commitment of those directly responsible for managing water at the operation (the site manager and team).

PART I: DRIVERS FOR LEADING PRACTICE WATER MANAGEMENT

1.0 THE BUSINESS CASE

KEY MESSAGES

- Water is an integral part of all operations—no mine operates without managing water.
- The business case for leading practice management of water is driven by the need to manage strategic and operational risks and opportunities.
- Risks and opportunities must be managed at both corporate and site level to ensure shareholder value is maximised, production is secure and the community and environmental values associated with the water are maintained or enhanced.
- Top level support and leadership is key to leading practice water management.

This chapter outlines the drivers for good water management. There are clear economic, environmental and social reasons to achieve it. Impacts of sub-standard water management may not only be felt at a local level but may escalate rapidly to become national and international issues, consuming large amounts resources. Too often water management is reactive and, because water is intimately linked to climate variability, there is a risk that management priorities become closely tied to current conditions; that is, excessive attention in times of scarcity or excess and none otherwise (see Hydro-illogical cycle case study).

There are financial consequences of poor operational water management. Running out of water can cost money in lost production and high water prices. If water is poorly managed, product quality can be compromised. Both these risks can result in loss of market share. Poor management of excess water can result in fines, loss of reputation and difficulties with environmental approvals. These risks can also cause issues with local communities and other water users, which may be very expensive to remedy in the long term. Lack of attention to the environmental and social services from water can erode the social licence to operate.

Beyond the operation, poor reputation for water management can contribute to loss of investment attractiveness, destruction of shareholder value, access to other resources (water, ore, land), licence to operate and difficulties in the area of attraction and retention of key staff. These strategic risks may be far more financially damaging than those at the operational level.

It is a common misconception that water management is solely an environmental task. This perception can severely limit the implementation of good water management practice since it

is necessary to ensure that both operational and business risks associated with water management are well controlled by a team sourced from all aspects of mine site operations.

For a mining operation there are three fundamental services provided by water that must be managed to meet business and sustainable development obligations.

1. Its involvement in mineral commodity production (all activities and all stages of the life cycle).
2. Maintenance of the ecosystems from which it is extracted and into which it is released.
3. Maintenance of the social and cultural needs it delivers.

The business case for leading practice water management is based on how an operation goes about managing risks associated with delivering these services and how this management contributes to the control of higher level strategic risks across the corporation. Environmental compliance is gradually becoming more stringent. Operating beyond compliance is good practice from a social licence perspective and a sensible proactive business strategy.

1.1 Strategic risks

A number of strategic risks emerge for the corporation if threats/hazards are not effectively managed and company reputation is compromised and/or company standards, values and ethics are not being adhered to.

1. Company reputation is increasingly linked to **investment attractiveness and shareholder value**. A significant amount of effort in corporate sustainable development policy and practice is targeting investment.
2. There is also a clear and valuable link between company reputation and **access to resources**. A good reputation for water management will improve chances that ore bodies in sensitive locations can be accessed and that approvals will not be delayed.
3. At a time of global skills shortages companies have demonstrated that a good reputation results in better **workforce relations** with positive impacts on staff attraction and retention.
4. The financial implications of poor performance in managing the strategic risks can be much greater than the direct operational-level risks. Ultimately, they can compromise the permission society gives to the industry to produce minerals—the so-called **social licence-to-operate**. Since the interaction between local communities and mine water contexts are highly variable, no one approach will satisfy all situations. Societal perception exists at many levels of aggregation, from the local community around a mine to the global community's views of the mining industry. Therefore, approaches designed to manage social licence issues surrounding water need a layered approach and also to be consistent with the range of other strategic and local issues over which engagement with communities is occurring. While good water management is not always the most important contributor to reputation, there are many examples where it is a major component. This importance is growing, especially in the context of the future threat of climate change to water resources in many regions of the world.

Mitigation of operational and strategic risks may present opportunities with positive benefits. Risk in its broadest sense is deemed to have positive and negative consequences (threats and opportunities). Threats in one context can become opportunities. For example, onsite water treatment and blending may be implemented to improve assurance of supply with additional benefit of delivering corporate freshwater reduction targets. More generally there are moves towards aligning language and intent. For example, increasingly, the word 'waste' is being avoided due to changes in attitudes and technologies converting waste into resources. In this handbook, for example, there is a shift from 'waste' water to 'worked' water.

1.2 Operational risks

Operational-level risks involve water quantity and water quality and, in many cases, both at the same time. They have significant potential to damage reputation with other water users, the community generally, and workforce.

1. Insufficient attention to **security of supply** can result in water shortages with associated reduction in revenue from loss of production, payment of high prices for water by trying to purchase it in dry times and/or potential loss of market share due to perception of unreliability of product supply.
2. Poor management of **water excess** can result in breaches of licence (with associated fines and loss of community support for the operation) in the event of uncontrolled discharge and, when excess water is acquired from extreme rainfall events, errors in keeping the appropriate amount of water can compromise the viability of the operation in dry times.
3. Inadequate attention to **water quality** management may result in reductions of mineral recovery or compromises to product quality, both of which will not be well regarded by the market, for example, the REACH[1] provisions, and/or additional costs in managing excess water on site. Personal health and safety may also be compromised. Further, significant fiscal and reputation costs can be associated with inability to cope with impacts of discharge of poor water quality on aquatic ecosystems, and agricultural and recreational water values (fish kills, stock and human health impacts) within the lease and in the receiving environment. Equally, unnecessary over-use of fresh or potable water when other quality water would suffice can undermine the reputation of a company as being a good manager of water.

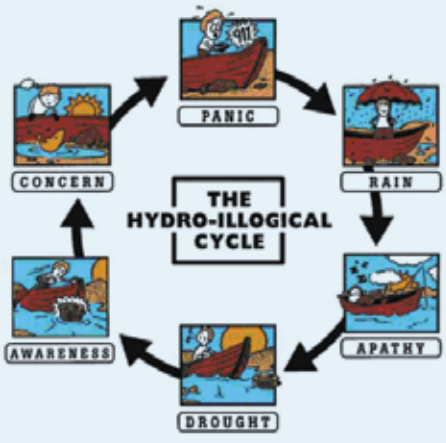
1 REACH is regulation EC 1907/2006 concerning the registration, evaluation, authorisation and restriction of chemicals.

4. Poor **operational practices** and resultant inefficiencies leading to penalties and 'hidden costs', such as water volume charges and maintenance costs, and expensive environmental legacies at closure.

CASE STUDY: The Hydro-illogical cycle

Given the impact of climate change on water resources and consequent focus on leading water management practices, why is it often difficult to sustain effort and promote proactive management? It is suggested that the concept of the "hydro-Illogical cycle" assists in explaining this conundrum in the mining industry (as well as in the wider community). The problem revolves around the fact that risks associated with water management are most in focus when facing imminent production impacts, either due to scarcity of water or needing to deal with excesses in flooding. Scarcity (or excess) often coincides with climatic extremes, which may dissipate rapidly after an extreme event.

Using the case of scarcity as an example, following a period of normal rainfall, focus on water management may be very low in the hierarchy of management priorities evidenced by an apathetic approach to the importance of water. As conditions gradually become drier with lack of rainfall, awareness of the potential impacts of water shortage on production is heightened and the management team begins to become concerned. As conditions continue to get even drier it becomes apparent that water scarcity may directly impact production. At this stage panic sets in and a flurry of activity occurs to attempt to secure additional water and save water. Meetings are held at the highest level and funds are committed to "solving the problem" at the eleventh hour. Neither expense nor effort is spared (National Drought Mitigation Centre (www.drought.unl.edu/plan/cycle.htm)).



The Hydro-Illogical Cycle. Image Source: Rio Tinto

Inevitably the drought breaks, possibly before the emergency scheme or solution has even been implemented, panic subsides, and advanced execution plans may be immediately shelved without addressing the real cause, such as the assurance of supply or getting the plans to a logical point of conclusion for later action. Importance subsides and water issues are dropped down the hierarchy of management priorities. Concern over water and awareness becomes amnesia.

Tactical reactive responses to lack of water under conditions of panic rarely lead to strategic structural, or foundational changes which would strengthen the operation against future cycles, for example, robust water management plans, tested water balances and so on The Hydro-Illogical cycle is repeated (often several times) before the lesson is learned. A similar cycle can be described in cases of water excess where excess is a problem and impacts production.

2.0 GOVERNANCE

KEY MESSAGES

- Governance is the way corporations, governments and individuals share rights and responsibilities, and establish accountabilities and processes among stakeholders/participants for the effective management of water.
- A mixture of formal and industry self-regulation is applied to deliver water outcomes on the basis of shared responsibility.

Governance can be defined as the set of authorities, processes and procedures guiding decision making. The board of the corporate entity, ultimately responsible for the operation sets the expectations for how water will be managed. This includes complying with the legal and licence requirements for water resources and environmental protection set either in legislation for all operations or established as part of the licence conditions at the time the operation's activities are formally approved. In Australia, there are government regulations, authorities and responsibilities for water at federal, state and local levels. Although the states have primary authority for water allocation under the Australian Constitution, the federal government exercises control over water through a number of fiscal and regulatory instruments. For example, there can be important implications for water management if the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* is triggered. There can also be a significant influence from the community over decision making regarding water management, often referred to as the 'social licence to operate'.

2.1 Corporate

The mining industry uses a range of self-regulatory approaches for water management. These are mandated from the level of the company board and take the form of overarching principles, operating strategies and quantitative targets. The Australian mining industry has embraced sustainable development as its operating paradigm and this is evident through the development and implementation of *Enduring Value—the Australian Minerals Industry Framework for Sustainable Development* (www.minerals.org.au/enduringvalue). *Enduring Value* translates the International Council on Mining and Metals (ICMM) 10 principles of sustainable development into practices, at the operational level, in a manner which is attuned to the expectations of the community and which seeks to maximise the long-term benefits to society.

There is increasing scrutiny on all water users in regard to their use and management of water. The role of corporate sustainability reporting, such as via the Global Reporting Initiative (www.globalreporting.org/Home), is one method by which mining companies are voluntarily committing to and reporting on improvements of water usage. The rationale is to articulate the contributions made by industry to water stewardship, based on a triple bottom line approach, which exceed statutory requirements and allow industry to review and improve practices.

2.2 Government

Responsibility for water remained with the states at federation under Section 100 of the Australian Constitution. This led to different jurisdictional approaches to managing water, which did not consider competition, equity of access to water and integrated management, and non-optimal handling of rivers and aquifers that traverse state borders.

In 1994, the Council of Australian Governments' Water Reform Framework was initiated. This acknowledged the need for a national approach to governance for the efficient and sustainable use of water resources. The framework was extended in 2004, with the introduction of the National Water Initiative (NWI) (www.nwc.gov.au/nwi/index.cfm), which is the principal policy for national water reform, aimed at achieving improved efficiency and productivity of water use by restoring over-allocated water systems to sustainable levels, and removing barriers to trade. Central to the NWI is a nationally consistent approach to the management of water access entitlements.

Paragraph 34 of the NWI recognises that the mining sector can face special circumstances which may require specific management arrangements that are beyond the scope of the NWI Agreement. This is in recognition of factors such as isolation, relatively short project duration, water quality issues and obligations to remediate and offset impacts.

At an operational level, state-based legislation is the predominant statutory instrument that is applicable to the mining sector in regard to water access, use and discharge. Statutory approvals and licence conditions are applied over the life of an operation. State legislation, policies and administrative processes relating to water management vary between jurisdictions, so awareness of state-specific requirements is required.

Approvals and licences may stipulate operating conditions, including quality, quantity and timing under which water can be accessed and discharged. Significant guidance on application and derivation of compliance standards for water quality is provided by the National Water Quality Management Strategy (NWQMS) (www.environment.gov.au/water/quality/nwqms/index.html). State and territory regulators and industry utilise the guidelines to derive appropriate discharge criteria.

In most states, water allocation is carried out periodically through the interaction of a local co-ordinating group and the state agencies. Allocations to the mining industry may be

changed if the hydrological conditions are deemed to have changed and/or the previous estimates of sustainable yields are brought into question with new data or modelling. Industry representation in the water planning processes is generally via industry councils, such as NSW Minerals Council, Queensland Resources Council and Western Australia Chamber of Mines and Energy.

2.3 Rights to waters and the Native Title Act

The mining industry is committed to respecting the connection and special interests of Indigenous people to Australia's lands and waters, particularly native title rights and interests.

Native title refers to rights and interests held by Aboriginal peoples or Torres Strait Islanders in lands and waters that derive from their traditional laws and customs. Native title may exist in relation to land and water where the following conditions are met:

- the rights and interests are possessed under the traditional law acknowledged and the traditional customs currently observed by the relevant Indigenous people, where the laws and customs have been acknowledged and observed in a substantially uninterrupted way from the time of European settlement until the present time.
- those Indigenous people have a connection with the area in question (including waters) by those traditional laws and customs.
- the rights and interests are rights and interests which are recognised by the common law of Australia.

Native title rights can consist of 'exclusive' or 'non-exclusive' rights in relation to lands and waters. Native title rights relating to water are generally non-exclusive rights, and are usually restricted to the right to use waters for personal, domestic or non-commercial communal needs, including for the purpose of observing traditional, cultural, ritual and spiritual laws and customs. Areas where native title rights in waters may exist include oceans, seas, reefs, lakes, rivers and inland waters that are not privately owned. However, there is still some uncertainty as to the exact nature of native title rights and interests in onshore and offshore waters, and the extent of any native title rights in a particular area will depend on the traditional laws and customs from which they are derived, and the extent and nature of any other existing rights in relation to the area.

Where native title is recognised, it must co-exist and is subject to, any validly granted non-native title rights and interests in the native title area. As noted above, native title rights relating to waters are generally restricted to a purpose of satisfying personal, domestic or non-commercial communal needs, including the purpose of observing traditional, cultural, ritual and spiritual laws and customs.

The *Native Title Act 1993* (Cth) (NTA) provides for the recognition and protection of native title rights and interests held by Aboriginal peoples and Torres Strait Islanders. The NTA provides a mechanism for the determination of native title over an area of land and/or

waters. The majority of native title determination applications are made on behalf of Aboriginal peoples and Torres Strait Islanders and are referred to as 'claimant applications'.

The future Act regime in the NTA provides a number of different procedures to ensure that acts that might affect native title ('future Acts') are valid. An Act affects native title if it extinguishes the native title rights or interests or if it is otherwise wholly or partly inconsistent with the continued existence, enjoyment or exercise of the native title rights or interests. The granting of interests, permits or authorities allowing mining and mineral development activities are generally acts which affect native title rights and interests.

2.4 Shared responsibility

The mining industry recognises it has a shared responsibility with government and society to manage water sustainably, and has undertaken several initiatives to improve the understanding and management of water to provide guidance on and share current leading practice. For example, the development of a *Strategic Framework for Water Management in the Minerals Industry* provides high-level guidance for operations on developing a water strategy based on life-of-mine water stewardship principles (www.ret.gov.au).

The value of water is rising due to growing demand and increasing scarcity. To address issues such as over-allocation in some systems and the need to ensure sustainable yield and environmental flows, the evolution of water governance in Australia places increased focus on responsible water use and reuse. Recognising the vital importance of secure access to water for mining operations, there is a need to abide by current statutory requirements while building capacity within the mining sector to use water more efficiently and demonstrate leading practice at the operational level. A summary of the water resource planning legislative framework for each state and territory can be found in ABS (2006, Appendix 2) and ACIL Tasman (2007).

3.0 ESTABLISHING A WATER MANAGEMENT PROGRAM: PRINCIPLES AND KEY RISKS

KEY MESSAGES

- Leading practice water management can be achieved by adhering to a set of principles consistent with ISO14001 standards.
- Listing and implementing site controls for a concise checklist of key threats and opportunities is suggested as an effective mechanism for achieving leading practice

For any operation to establish leading practice in water management there are several key principles that staff at all levels must understand to ensure continued improvement and success. This chapter will document these principles and highlight a number of technical considerations which require specific understanding and attention. The conceptual flow model outlined in Part III emphasises the potential complexities of water management. By referring to the following principles and considering in detail each of the elements of the model in Part III, a workable water management program can be established.

3.1 Key principles for water management

The following principles (aligned with international and Australian Standards) are guidance for consideration when developing processes to improve water management.

3.1.1 Leadership and commitment

- management at all levels of the operation must be engaged and prepared to lead and follow through on commitments made;
- clearly articulate the operational importance and commitment by the most senior operational manager;
- ensure water is considered in corporate and operational policies; and,
- link in the operational goals with corporate goals where applicable.

3.1.2 Planning

- ensure the water context, for example, dry/wet, arid versus tropics, seasonal, ground/surface water dominance, urban/remote, environmental sensitivity and so on, is understood and documented as a basis for design and implementation of changes and operational procedures;

- ensure that a baseline evaluation of the water resource at an operation is undertaken initially and that the results benchmarked;
- ensure community expectations, including post-closure issues, are understood and the extent to which they can be met are clearly recorded and communicated;
- assess the potential water threats and opportunities to the operation and external stakeholders including the general environment;
- ensure full account of potential post-mining legacy issues from the outset;
- ensure that legal and other requirements are appropriate and complied with;
- consider what controls, objectives and targets are required to ensure improvement is attained; and,
- are there specific water management strategies/policies/plans required for individual areas of the operation?

3.1.3 Implementation

- water efficiencies should be considered in design, fabrication, installation, commissioning and then in ongoing operations;
- adequate resources (financial, human, time) must be allocated;
- clear accountabilities for water management must be articulated in position descriptions and form part of performance reviews;
- all tasks involving water should use water fit-for-purpose;
- water management must be integrated into and aligned with the day-to-day business objectives and risk registers;
- management must make staff aware of the need for water management and motivate them to be engaged and contribute to achieving positive outcomes;
- specialist training should be provided where needed to enhance the skill base;
- water management programs need to be communicated, results recorded and successes celebrated; and,
- emergency planning should consider scenarios of excessive water, lack of water and change of quality issues.

3.1.4 Measurement, evaluation, review and improvement

- the methods used for measurements of water quality and quantity must be consistent with accepted national standards; that is, detection limits, accuracy and precision;
- water monitoring programs should be sufficiently comprehensive to enable operations to identify issues so that corrective and preventive actions can be taken;
- data collection systems should be fit-for-purpose and enable trends to be identified and managed;
- corrective actions identified from monitoring programs should be documented in water management strategies/policies/plans;
- water management plans should be reviewed at least annually and updated to ensure use of the resource is continually improved; and,
- operational information systems should be designed to be operator-independent, capable of reporting for multiple purposes, and secure.

CASE STUDY: Rio Tinto water diagnostic

"Excellence in Water Management" water diagnostic program

The Rio Tinto "Excellence in Water Management" diagnostic methodology was developed to provide a holistic assessment of water management at an operation (mine site, smelter etc). The full engagement program takes the operation from initial risk-based performance assessment relative to key performance areas (KPA), to risk reduction opportunity workshops and finally to project planning and scheduling of prioritised action plans.

As at end 2007, Rio Tinto has utilised this diagnostic methodology at more than 25 of its operations globally, giving rise to projects that reduce water-related risk and improve water efficiency at the operations. Leading practice and high-risk trends are identified from these operational reviews allowing targeted corporate programs to be developed.

Risk review/performance assessment diagnostic workshop

Participants with both management and operational backgrounds are needed to provide a breadth of understanding and technical knowledge of water management as well as operational reality. The workshop is facilitated by experienced diagnostic practitioners supported by technical specialists, should the operation have site-specific challenges.

The workshop involves a facilitated self-assessment review of water management for the site in question, using the diagnostic tool in order to evaluate current performance of the operation against 14 KPAs on an interactive and collaborative basis. KPAs cover areas across the water life cycle including: water strategy and planning, site water balance, water efficiency/targets/recycling, surface and groundwater management, supply and disposal assurance, infrastructure, tailings, monitoring, personnel/skills management, and closure.

Participants at a diagnostic workshop. Image Source: Rio Tinto

During the workshop, which typically takes a day, the team evaluates the current status of each KPA on a rating scale from 'not addressed' through to 'leading practice'. The importance of the specific KPA for both current operations and future expansions (if appropriate) is rated and a risk rating associated with current practice assigned. Risks are categorised into four risk levels, from 'immediate' action (critical) through to retaining a 'watching brief' (low risk). Risks may include technical, environmental, reputational and financial components. Qualitative information is also captured to provide context for the results.

The diagnostic tool facilitates immediate graphical and text output of the assessed performance ratings for all KPAs, and prioritisation/categorisation of risks.

Identification of risk reduction opportunities

Key personnel with operational or expert knowledge are gathered to identify opportunities to improve performance and mitigate risks identified in the diagnostic workshop. This is undertaken in a structured brainstorming environment aimed at stimulating problem solving.

During the workshop participants propose opportunities for improvement for risk mitigation. All opportunities are discussed and assessed in order to reach consensus on context and relative merit of risk reduction/implementation cost/likelihood of success/ cost benefit and time to implement. The best (highest ranked) opportunities are agreed and detailed action plans developed.

Planning, scheduling, approval and monitoring

Standard project planning tools are utilised to develop agreed budget and implementation programs for management approvals. The diagnostic methodology may be rerun at the site in order to monitor improvement and confirm priorities.

3.2 Key water system risks

Sections 1.1 and 1.2 describes the key risks associated with the business case for leading practice water management. Many of these risks are consistent with those factors that need to be addressed to ensure the effective implementation of sustainable development practice. In this section (Table 2), the key risks for water management and their causes are summarised.

Table 2. Strategic risks associated with the business case for good water management

RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	THREATS
Investment attractiveness	Company reputation is reduced due to poor water management, lack of attention to efficiency, environmental requirements, safety, security of supply.	Company/mining industry seen as preferred investment proposition.	Investors prefer other entities with similar financial returns but better reputation.
Access to resources	Government/regulators prefer to provide access to resources (water, ore, land) to companies with reputation for good management.	Access is given to resources without delays.	Ore bodies may become unavailable and/or approvals may be delayed.
Workforce	Employees perceive that the company is not managing water well and/or not providing them with sufficient amenity, for example, sporting and recreation green space in remote towns.	Productivity is high with a content and loyal workforce.	Difficulties recruiting and keeping staff. Potential to slow growth and reduce operational performance.
Infrastructure security	Changing nature of extreme climatic events, such as size of extreme hydrological flows. Attempts by activists to disrupt production.	Insurance premiums may be reduced if infrastructure is clearly secure. Lower cost overheads. Safety more assured.	Expensive infrastructure replacement. Environmental rehabilitation costs if breach occurs. Inability to get supplies in times of scarcity because suppliers prefer to deal with competitors who are in better favour with community. Safety is potentially compromised.
Social licence to operate	Poor reputation for water management creates community pressure to exclude company/industry from access to resources. Not meeting corporate social responsibility.	Community sees the mining industry as a good long-term option for use of water given competitive environment for water access.	Industry viability, access to ore bodies potential slowing of approvals and difficulties with ongoing operational efficiency (loss of production time due to social disruptions).

Table 3. Operational risks associated with the business case for good water management

RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	THREATS
Not enough water (lack of security of supply)	Poor planning—lack of understanding of supply reliability/capacity compared to demand. Change in legislative arrangements change volumetric access. Lack of attention to meeting design efficiencies creates higher than expected demand. Insufficient attention to climate and hydrological variability/shift/changes in design and/or operations.	Strategic control over water security provides regulator, community and investor confidence in operation/company. Opportunities to out-compete and potentially purchase operations that become non-viable because of lack of water.	Reduction in revenue from loss of production, payment of high prices for water by trying to purchase it in dry times and/or potential loss of market share due to perception of unreliability of product supply. Potential damage to reputation with other water users, the community generally, and workforce.
Too much water (excess supply)	Poor design or not operating to necessary standards to deal with excess water results in environmental breach, safety or health incidents or loss of production.	Possibility of supplying third party users and/or water trading. Appropriate storage may reduce demand for raw water reducing costs and/or allowing others to access raw water.	Loss of production. Breaches of licence resulting in fines. Loss of community support for the operation. Site, company and industry reputation damaged.
Water not fit-for-purpose (Water quality)	Lack of design for meeting water needs with water of appropriate quality (not defining fit-for-purpose standards). Inattention to operational management of design. Poor planning for extreme events. Poor planning for hydrological and/or climate variations.	Minimises water withdrawn from the environment. Positive reputation as good water manager if appropriate quality is used (minimising unnecessary use of potable or fresh water).	Mineral recovery reductions. Product quality compromises which will not be well regarded by the market, for example, the REACH provisions. Additional costs in managing excess water on site. Significant fiscal and reputation costs associated with impacts on environment (on- and off-site) and other users.

RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	THREATS
Closure liabilities	Poor water planning during operations and/or not taking into account changing circumstances.	Significant reputation growth with successful closure. Community content (supportive of) other operations/ expansions. No delays on access and/or approvals.	Poor reputation resulting in long term (possibly permanent) liabilities and associated costs.

PART II: MANAGEMENT AND REPORTING SYSTEMS

4.0 OPERATIONAL MANAGEMENT (TOOLS AND PROCESSES)

KEY MESSAGES

- Leading practice water management is achieved by adhering to formally agreed operational processes and implementing supporting tools.
- A site-specific strategic water plan and regularly updated water management plan are essential for achieving leading practice.
- Operational procedures supported by an accurate, 'as-built', water circuit diagram, water accounts developed by applying water balance disciplines, and effective site monitoring provide the necessary components for managing site risks/opportunities.

This chapter outlines the key planning and management procedures and documents that a leading practice operation would use. The major risks associated with water management that operations and corporations are likely to face are described.

Water issues traditionally cross a number of management boundaries. Water management is often fragmented. Water input, output, diversion, operational use (use-treat-store) and performance reporting often reside within different departments (Table 1). This approach is prone to duplication of services, ineffective planning, unnecessary water losses, ineffective water use efficiency programs and compliance-driven performance monitoring/reporting; it is not leading practice.

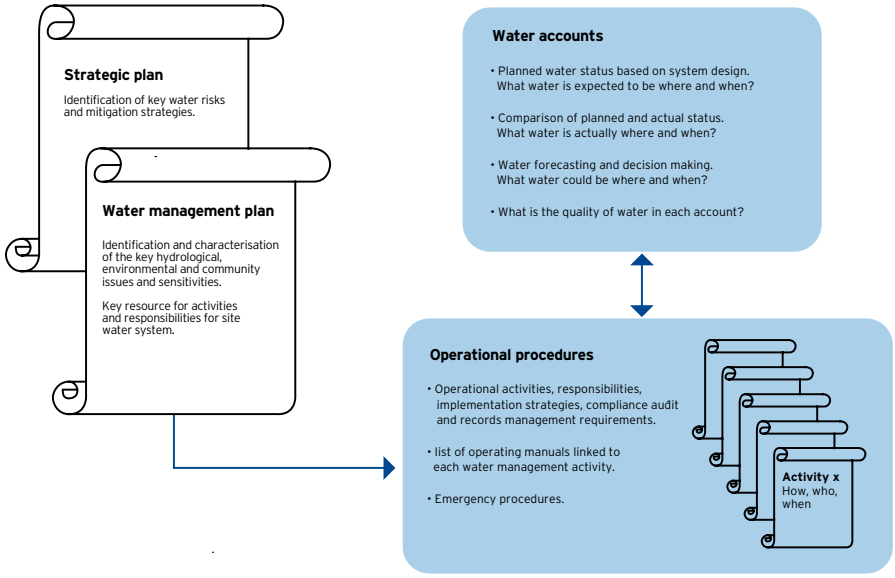
Leading practice dictates that water management on a site is integrated across departments with a coordinating body chaired by the operational manager. This team is responsible for the operation's water management plans, tools and processes (Figure 3).

These tools and processes, in particular the water accounts and methods used to derive them (see below), can be used to unravel the complex interactions between observed water system responses to a particular event and the causal processes. This approach provides a quantitative understanding to support robust decision making—from the level of the general manager to the environment officer and the regulators. A well maintained, up-to-date and robust water account is an essential feature of a leading practice operation.

4.1 Strategic water plan

The strategic water plan is a key tool in managing long-term business risks and opportunities. It is a high-level management tool that documents the business case for site water management over the life of a project. The development of this plan is covered in detail in the MCMPR (2006) *A Framework for Strategic Water Management in the Minerals Industry* booklet and reflects the outcomes from risk and option analyses.

Figure 3. The main components of the planning and processes required for leading practice water management.



4.2 Water management plan

A comprehensive site Water Management Plan (WMP) is fundamental to leading practice water management. Its size and complexity depends on the nature of the operation, hydrology, and the cultural and environmental sensitivity of the surrounding area. It is a public statement about how to manage both operational use of water and potentially adverse impacts of operations on the local and regional water resources. The WMP identifies all water management issues associated with developing, operating and decommissioning a project. The main water issues to be covered at each stage of the life cycle (see Figure 2) are summarised in Figure 4.

The WMP integrates water quantity and quality. It provides a general overview of the mine site hydrology, what management measures are in place and who is responsible for implementing these. The WMP records specific site water objectives against which performance can be assessed—quantitative objectives are preferred for effective auditing of

performance. The WMP also records any requirements for internal and external reporting of water performance, ensures periodic reporting is recorded in operational procedures and links to operational manuals. It should be in frequent use and accessible to all staff via the company Intranet. The WMP is dynamic and should be regularly updated and reviewed.

4.3 Operational procedures

Operational procedures provide checklists of procedures for the site water management system. They describe the required operational activities and define battery limits, responsibilities, implementation strategies, required compliance audits and records management. The procedures also list operating manuals linked to each water management activity and relevant emergency procedures. Operational procedures define the assumptions upon which the site's water account is based and, consequently, upon which management decisions are made. It is essential that management systems are put in place to ensure that the procedures are acted upon, otherwise the water management system may not perform as intended. This is an internal document that forms part of the environmental management system.

Figure 4. Activities at various stages of a mine's life cycle.

I. Exploration	IV. Shipping of products
■ Temporary water supply ■ Impacts of water management on local ■ Water resources/users ■ Potable water treatment ■ Discharge of excess drilling water ■ Waste water disposal ■ Site stormwater management	■ Spillage, dust control
III. Resource development and design	**V. Rehabilitation**
■ Water supply – identification and quantification ■ Impacts of water abstraction/diversion on local water resources/users ■ Government approvals ■ Water supply, storage and treatment (design and construction) ■ Dust suppression and dewatering discharge ■ Waste water disposal ■ Site stormwater management	■ Post-mining landform drainage design ■ Contaminated site remediation ■ Borefield and water supply scheme decommissioning ■ Decommissioning of mineral processing and transport facilities ■ Mine pit lake modeling and formulation of closure strategies ■ Stakeholder approval and development of catchment management plans
III. Mining, minerals processing and refining	**VI. Post-mining and closure**
■ Water supply management ■ Water treatment (worked water and potable) ■ Mine dewatering ■ Worked water recovery, storage and reuse ■ Worked water disposal (discharge management) ■ Dust control and contamination management ■ Catchment management (including AMD) ■ Performance monitoring and reporting	■ Rehabilitation performance monitoring ■ Erosion control and drainage maintenance ■ Contaminated site remediation verification ■ Stakeholder and regulatory sign-off

An important part of a site's operational procedures is to define the different waters that may have to be managed on the site. This provides the base for clear water accounting and ensures that output from the site water account is consistently interpreted. Essentially water

has two states—raw (not previously passed through a task) and worked (passed through a task at least once). A number of sources of water are potentially available (Table 4). The term fresh water is a sub-set of raw water. Give the importance of communicating with communities regarding use of fresh water, operations should have a definition of the quality attributes that constitute fresh water and a record of its sources.

4.4 Water accounting

Leading practice sites can demonstrate that they know the quantity and quality of water in their stores, the flows between tasks and stores and the rates of water input and output to and from the site. This information is fundamental to designing the water system, making appropriate decisions regarding its use, assessing and reporting on its operational performance and strategic planning of changes needed in the system. In short, leading practice sites can account for their water and its condition, and can effectively manipulate these to meet site requirements.

A summary of the key requirements for leading practice water accounting is given in Figure 5. Site data and operational procedures (operating rules, constraints and appropriate assumptions to close data gaps) are inputs to an operational simulation model which resolves water balance, through the components specified by the circuit diagram, to produce one or more water account.

Table 4. Raw (primary) and worked (recycled) water sources.

RAW (PRIMARY) WATER SOURCES	WORKED (USED/RECYCLED) WATER SOURCES
Surface water resources (rivers, lakes, dams, clean runoff)	Direct: Tailings thickener overflow
Groundwater (surficial, sedimentary and fractured rock aquifers)	Concentrator/thickener overflow
Seawater (with possible) desalination	Filtration plant filtrate
Rain interception	Site stormwater runoff—roads/ disturbed/industrial areas
Town-metropolitan water utility supply	In-direct:
Treated sewage effluent	Tailings dam decant water
Mine dewatering	Irrigation return flow
	Washdown bay discharge
	Acid mine drainage
	Stockpile and waste rock dump runoff and seepage
	Industrial waste water treatment plant effluent.

4.4.1 Water circuit diagram

The site water circuit diagram (Figure 5) specifies the components of the water system represented in a water account. It carries information on infrastructure, hydraulic and capacity properties of components and the flows between them. It also includes interactions between the physical infrastructure and the landscape hydrological components which interact with it. Points of water input to and output from the site are indicated.

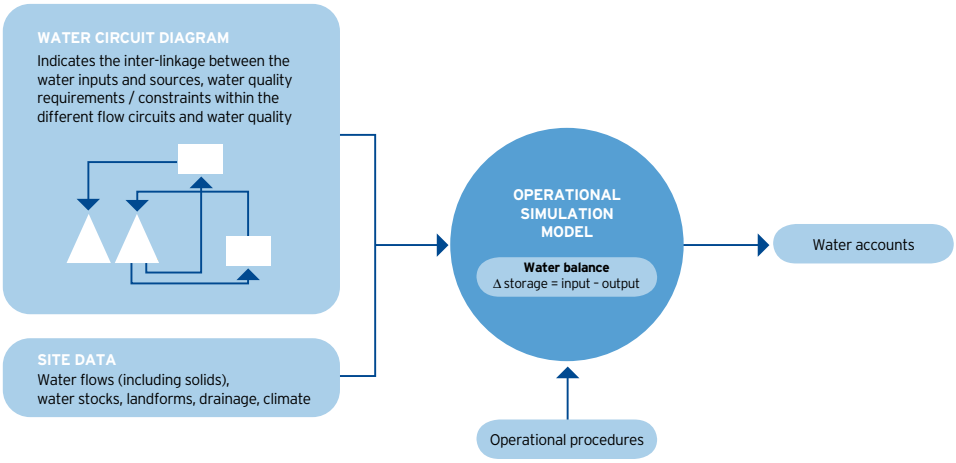
4.4.2 Site data

Leading practice is unattainable if operations do not keep an up-to-date, well managed information system for storing, maintaining, analysing and reporting site data. Some data change rarely, like average monthly potential evaporation, and others almost constantly, like water levels in process ponds. Chapter 5 provides guidance on how to establish and maintain an effective monitoring system.

4.4.3 Operational simulation model

An operational simulation model is used to derive the information that is needed to formulate a water account. Water auditing—the determination of volumes of water sources, destinations and inventories—provides necessary, but insufficient, information for the water accounts. The operational simulation model is used to provide the rest. It combines monitoring, site and climate data with the water audit results and uses representations of physical processes, for example, estimations of the conversion of rainfall to runoff, evaporation and seepage, and infrastructure performance, to close water balances. The term 'close' is used to describe the process of accounting for all the water in the components of the circuit diagram even though direct measurements are unlikely to be available at all locations. A common oversight in operational simulation modelling is incomplete representation of the water associated with movement of solids and changes of moisture content, for example, wetting of coal at the longwall face as a result of dust suppression or water entrained in tailings.

Figure 5. Requirements to formulate water accounts.



Model calibration is an important process in ensuring reliability. It involves the comparison of derived flows at selected points with measured flows. This is done for a range of operating conditions that cover all control states. Model parameters are then adjusted to achieve a reasonable correlation between predicted and measured trends. This is best done by a modelling specialist who understands the implications of changes that are made to parameters.

Underpinning the calibration are site water (rate of change of water quantity and quality) data. It is essential that the techniques used for monitoring during both wet and dry conditions are comparable in precision and accuracy so that calibration is robust across a range of rainfall and hydrologic conditions. Site staff must be well qualified and trained in the methods used and remain motivated about monitoring so that equipment is well maintained and data are well managed. This is a challenge for line managers. The setting of key performance indicators linked to personal reward for water managers is likely to be an effective tool to ensure ongoing quality of performance.

Operational simulation models can be used to estimate the risk (or probability) of occurrence of an event. A climatic event (storm, cyclone, drought) and an associated water management system event (storage spill, water shortage, concentration level exceedence) do not share the same probability of occurrence. Simulation can determine these relationships. Experienced modellers sometimes use probability distributions as a mechanism to deal with data uncertainty. This approach can be powerful but is also open to misinterpretation of results and should only be carried out by a professional modeller.

What is water balance?

There is much confusion in the mining industry about the term 'water balance'. Water balance is simply a statement of the relationship between input and output of water across a defined system boundary, such as the lease boundary or concentrator. If input is > output then storage within the system increases; if input is < output then storage decreases. In simple mathematical form:

$$\Delta \text{ storage} = \text{input} - \text{output}$$

Therefore, water balance is a process or a discipline used to achieve an outcome. Generally that outcome is to determine the quantity of water in a storage and/or moving between tasks or storages, in order to support decision making and/or reporting.

The operational simulation model is a powerful management tool due to its predictive capabilities and ability to run 'what if?' scenario analysis. It is, therefore, essential that the operational simulation model resides with the operational staff and has an 'owner' or custodian who has the necessary skills to address the level of complexity that is required. Integration of this ownership and/or the data from the modelling exercises across functional management areas in the operation is vital. If water balance and the associated data are disassociated from operational teams and exist in group silos, for example, in environment or technical services, there is less chance of an integrated water systems approach being adopted and consequently less chance of a well operated water system.

4.4.4 Water accounts

A water account is like a snap shot of a water balance over a particular period of time. For operational decision making, this may range from hours to weeks. Annual accounts are often sufficient for strategic decision making and corporate reporting. The complexity of a particular water account is determined by its use. For example, detailed planning of a mine site expansion will require all details of the system to be included and reported as the basis for system design, costing and construction. For operational decision making it may be sensible to simplify the system so that the level of complexity and decision making are aligned. For example, there may be little value in representing small water bodies that are not a part of the site's water reticulation system. For strategic decision making and corporate/management reporting a significantly simplified version of the account will likely suffice. In this case the parts of the system which indicate overall performance or provide the greatest opportunities for improving performance can be the focus of attention.

Leading operations also include water quality representations in the water account. This may require increasing the complexity of the operational simulation model if geochemical transformations need to be taken into account or alterations associated with tasks, for example, mineral flotation, are included.

Water accounts can also be derived, through 'what if?' simulation, to examine alternative system designs or forecast, based on probable weather conditions, to support decision making. The scope, complexity and accuracy of water accounts may evolve as a project develops. Table 5 provides an indication of a range of water account types.

Table 5. Types of water account and their features.

ACCOUNT TYPE	FEATURES
Basic quantity (input, output, diversion and stores)	Approximations of store inventories and major fluxes between tasks.
Basic quantity and quality	Inclusion of water quality information as conservative concentrations/loads.
Advanced quantity/quality	Inclusion of chemical transformations and time varying flows.
Predictive—basic or advanced	Incorporates control logic and branches (alternatives). Continuous tracking of stores and flows. Inclusion of management changes to evaluate their effectiveness.
Predictive and statistically sensitive—basic or advanced	Incorporates representation of uncertainty and/or variability of conditions or site hydraulic/hydrological and mine conditions. Typically have statistical statements associated with water account entries.
Forecasting (probability)—basic or advanced	Uses forecasts of weather and/or mine operations possibilities to produce probable water account entries with accompanying statistical statements.

Table 6 illustrates a basic quantity water account. Mine X, a fictitious mine, must dewater because the ore is below the water table. The majority of the groundwater from dewatering is reinjected (diverted) and a small proportion is redirected to site tasks (460 megalitres) from where 100 megalitres is used to transport the concentrate off site to the port and entrained in tailings. Mine X also takes treated water from a local town effluent supply and has an onsite treatment; no marine water is input to the site. For the year illustrated, Mine X had a net accumulation of 205 megalitres in its site stores with 35 percent reuse and 22 percent of water was from recycling. Under current conditions (average rainfall and water balance as in 2006, the site would not run out of water as it has a net accumulation. However, in dry conditions simulation indicates the site could run out of water in only 2.5 years.

Table 6. Example of a basic quantity account for a fictitious mine.

Mine X Copper 2006

WATER SOURCE ACCOUNT

	VOLUME MEGALITRES PER YEAR				
	input	diversion	tasks	output	Δ store
Surface	780	0	300	200	280
Ground	15 000	13 800	460	100	640
Marine	0	0	0	0	0
Site stores	0	0	550	175	-725
Third-party	275	0	245	20	10
TOTAL	16 055	13 800	1555	495	205

WATER STATE ACCOUNT

	VOLUME MEGALITRES PER YEAR				
Raw fresh	15 000	13 800	460	100	640
Raw non-fresh	780	0	300	200	280
Worked	0	0	450	175	-725
Treated	275	0	345	20	10
TOTAL	16 055	13 800	1555	495	205

EFFICIENCY %	
Reuse	35
Recycle	22

	MEGALITRES
store capacity	12 000
inventory	7850

OPERATIONAL RISKS	CURRENT	WET	DRY
time to fill (year)	20.2	8	49
time to empty (year)	-	-	2.5

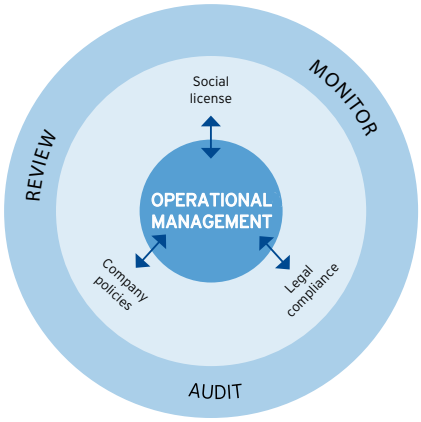
5.0 MONITOR, AUDIT AND REVIEW

KEY MESSAGES

- A foundation of progression towards leading practice water management is effective monitoring of performance, regular auditing and review processes at all stages of the mine life cycle to meet the goals set by the business case for leading water management.
- Formal documentation forms as an essential part of the improvement pathway.

Monitoring, auditing and reviewing are the processes and measurements required to assess whether management of the key operational and strategic risks is effective. Effectiveness must be assessed against the requirements set by the three areas of governance (Chapter 2) —corporate, government and community (Figure 6). The requirements from each of these areas should be embedded into the operational management tools and processes (Chapter 4). That is, monitoring, audit and review must be able to assure the operation's water performance with reference to the strategic plan, the water management plan, operational procedures and water accounts. Effective coupling between each of these processes is needed for leading practice management. The fundamental underpinning for such assurance is provided by physical monitoring of the water system—on site and off site. This chapter focuses on this aspect.

Figure 6. Monitoring, auditing and review support operational management through measurement and measurement evaluation.



5.1 Physical system monitoring

5.1.1 Essential features of leading practice

- environmental performance that exceeds regulatory requirements;
- adoption of systems with early warning capability including online, real-time data and time-integrated sampling systems;
- investment in development of monitoring techniques and/or ongoing refinement of techniques, for example, development of rapid biological assessment tools for in-situ monitoring;
- adoption of technologies for treating on-site water quality to ensure maximum reuse of process and mine water, reducing reliance on fresh, ground, and surface water supplies and reducing impacts on environmental flows;
- applying appropriate QA/QC and auditing of all procedures; and,
- developing site-specific guideline trigger values rather than using default values.

5.1.2 Principal objectives

The principal objectives of water monitoring are to optimise operational performance and minimise environmental impacts. This is achieved by managing on-site water quality and quantity in such a way as to minimise off-site impacts occurring via direct release (Chapter 10) or poorly-managed diversions (Chapter 9). It is on this that the operating licence will be granted. Monitoring requirements at various stages of the mine life cycle are indicated in Table 7.

5.1.3 Onsite monitoring

Onsite issues largely relate to water (and constituent) balances into, around and out of the operation. The water management plan must include the requirements of onsite monitoring. The priorities for metering and measurement are locations where: (1) there are large fluxes of water, (2) where water quality is significantly altered, (3) where an operational task is sensitive to changes in quality, and (4) there is a hazard to safety and/or human or ecosystem health. The overarching requirement is to ensure there is sufficient water for operations while minimising the probability of unregulated discharge or excess abstraction. A thorough site risk assessment on this basis will highlight priority areas for monitoring and indicate what should be measured and at what frequency.

Table 7. Typical water quality issues for the mining industry.

MINE-LIFE STAGE	WATER QUALITY RELATED ACTIVITY	ACTION
Exploration	Erosion from temporary roads Runoff of drilling fluids, petroleum products from drill pad construction and operation, camp wastes.	Initial baseline monitoring program developed (weather station, several water quality/biology sites, water flows).
Resource development and design	Developing water management plan. Preparing EIS.	Baseline inventory and monitoring at key sites, including those in reference catchment(s), implemented for water quality and ecological features.
Mining, minerals processing and refining	Discharge management. Possible acid-rock drainage. Tailings management. Solid waste management.	On-site monitoring (discharges, storage and holding dams, groundwater). Off-site monitoring of receiving system and reference sites (quality, flows, biology). Water management plan implemented.
Rehabilitation	Management of onsite water.	On-going assessment of impacts.
Closure and post-mining	Considering all possible future impacts (e.g. acid rock drainage).	Continued off-site and onsite monitoring.
Shipping of products	Possible spillage, dust control	Monitoring of receiving system and reference sites (quality, flows, biology).

Onsite water monitoring must provide feedback, in some cases in real time, to support the site operators in making decisions about water management. This requires thresholds to be set for key physicochemical indicators for each area on site, based on the likely tasks that the water will be put to (in other words, its use categories). For example, thresholds for acceptable concentrations in water for release (see Chapter 10) and for operational uses (see Chapter 8) should be determined.

Where groundwater is likely to be impacted by mining activities, such as near waste rock and tailings impoundments, groundwater monitoring bores are desirable to detect potential contamination that might compromise subsequent water use, for example, for stock, if such waters feed surface waters. Management to minimise such impacts might be required, including the use of recovery bores for treatment and/or reuse.

5.1.4 Off-site monitoring

The guidelines for receiving (off-site) water quality are defined by the Commonwealth (ANZECC/ARMCANZ, 2000a) and enforced by state regulatory agencies. A guide to their application in the minerals industry is provided in the handbook prepared by Batley et al. (2003). The most stringent guidelines are those for protection of aquatic ecosystems, as distinct from those for other values such as recreational water or water for agricultural use,

and these normally apply. The guideline values that apply in a given situation depend on whether the receiving waters are of high conservation value (99 percent ecosystem protection), slightly/moderately disturbed (95 percent ecosystem protection), or highly disturbed (80 percent or less ecosystem protection). This level of protection is determined in consultation with the regulator and other stakeholders. The guideline trigger values do not represent concentration limits, but values that if exceeded trigger further investigation to determine any likely impact. This usually involves looking at other lines of evidence (toxicity testing) rather than chemical measurement.

Understanding concentrations and loads

The concentration of a constituent in water is generally stated in terms of mass per unit volume of water. For example, metal concentration may be given in milligrams per litre. To estimate the quantity of a constituent (load) the concentration and water volume are used; that is:

load (mass) = concentration (mass/volume) x water volume (volume)

Load is often quoted over a fixed period of time due to the need to estimate loads in flowing water; that is:

load (mass/time) = concentration (mass/volume) x water flux (volume/time)

For pragmatic reasons salinity concentration is often measured using a surrogate known as electrical conductivity. The units of electrical conductivity are microSiemens or milli-Siemens percentimetre. A calibration is required to convert these units to *mass/water volume*.

The acidity of water (pH) is the concentration (or more accurately the activity) of hydrogen ions in the water.

Leading practice operators will routinely monitor the quality of onsite water and of the waters receiving their discharges or runoff, both upstream and downstream of their operations, as well as in waters in nearby reference catchments and/or background sites to ensure that any changes in ecosystem health can be interpreted in terms of natural events (storms, droughts, climate change) rather than assuming that only discharge water quality is important. Leading practice operations cooperate with neighbours to collect regional reference water quality data. This may be particularly helpful in semi-arid areas or areas where water flows occur infrequently at reference sites.

5.1.5 Monitoring programs

Monitoring goes beyond compliance with licence conditions and guidelines. It involves understanding the nature and relevant sensitivities of the receiving systems, and the processes by which water quality can be reduced, such that appropriate, sensitive parameters and endpoints can be selected to enable detection of underlying trends before detriment occurs. Monitoring that is only able to detect changes after an impact has occurred cannot be used to manage systems to prevent impact and minimise liabilities. A common misconception is that monitoring for compliance is sufficient to manage discharges. If the first measurement of change is one that fails compliance, it is too late to prevent it.

Monitoring for chemical contaminants and for physicochemical parameters is typical, but is often insufficient. Guideline trigger values for contaminants are dependent on contaminant bioavailability, which is generally not explicitly measured. Measurement of total or total-dissolved concentrations of contaminants can substantially overestimate the bio-available fraction. While chemical monitoring is commonly the best early-warning tool, it should be integrated with biological monitoring, testing both the impacts on sensitive indicator organisms (toxicity testing) and the effects on biological communities (ecological monitoring) (Chapter 10).

Using the data to appropriately inform management of unexpected changes in quality, requires appropriate systems for data reporting and analysis, both to reveal trends and to trigger action if agreed threshold/trigger concentrations are exceeded.

Details of how to develop and undertake a monitoring program that is consistent with international best practice are given in the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC/ARMCANZ, 2000b). The key elements are the sampling locations and frequency, and the composition of the suite of measurements. In particular, measurement sensitivity and timing of sampling need to be matched to the local situation.

Leading practice requires a monitoring program that has an early detection capability that triggers a management action in response to an identified trend away from baseline and/or when an agreed threshold or trigger investigation level is reached. These 'triggers' should be conservative such that they are materially below the values at which unacceptable ecological damage will occur.

Appropriate quality assurance and quality control (QA/QC) is essential in both sampling and analysis. Ideally, chemical analyses for key contaminants should be undertaken by an accredited laboratory (NATA or equivalent). Only a limited number of commercial laboratories offer analytical limits of detection that are adequate to measure compliance with the guidelines specified for protection of high value aquatic ecosystems (99 percent protection) or for slightly to moderately disturbed aquatic ecosystems for some parameters (95 percent protection). There must also be adequate traceability of derived results to primary data, with verification of performance using certified reference materials and related QA/QC protocols.

Biological monitoring to check compliance with waste discharge licences is being increasingly required by state water regulators. While this is likely to be beyond the staff capabilities of most operations, there are commercial exotoxicology testing laboratories that can measure the toxicity of mine effluents using a suite of test organisms, and biological consultants who can provide local assessments using appropriate ecosystem monitoring tools. Guidance on field monitoring of biological community abundance and toxicity is provided in Batley et al. (2003).

The monitoring program should be adaptive, with processes for review and continuous improvement as knowledge and understanding increases. It should be viewed as both an ecological risk assessment of the impacts of the operation and an assessment of internal environmental performance.

5.2 Performance assessment

Performance is assessed by comparing data from the site, either from monitoring or modelling or both, with site water objectives included in the water management plan. It is important in reporting on objectives that reasons for meeting or not meeting objectives are seen as integral to reporting. Objectives can be written in such a way as to make reporting clear and simple. For example, the objective could include how it will be measured and what target values should be reached by what dates.

Data analysis and reporting will be an ongoing process, and will include both internal and external obligations. Internal reporting will assess the performance of management systems and the need for modifications, including possible treatment of discharges. External reporting to stakeholders including regulators, will demonstrate the operation's impact on the external receiving environment.

At least on an annual basis, the water management system should be reviewed through analysis of data records, incidents or issues, to determine if the water management system is operating effectively and that the procedures and monitoring programs are adequate.

5.3 Management processes

While physical monitoring is of primary importance, leading practice dictates that management procedures to ensure that processes are being followed and tools are up-to-date are in place. Risk registers must be demonstrably changing over time because the significance of risks evolves as mitigation is implemented and as the site's operating conditions change. The strategic plan and water management plans must include provisions for update, audit and review. Plans without these are not leading practice.

5.4 Auditing

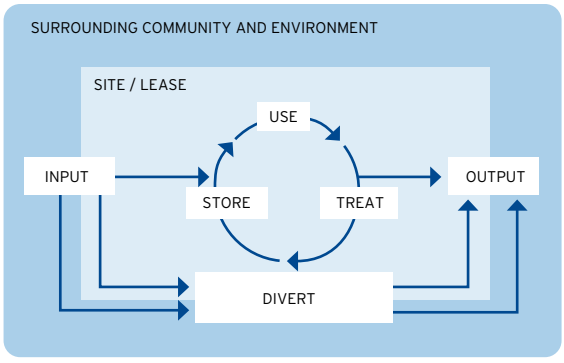
Auditing is essential to determine whether the monitoring system is operating according to design. It should assess adherence to appropriate QA/QC, the training and capability of monitoring staff, and the usefulness and reliability of any conclusions drawn from the data in relation to identification of trends, causes and impacts. It should also assess the safety of all field and laboratory operations. Internal audits are more frequent than external audits (for NATA-accredited laboratories these are annual).

Water quality monitoring should be a component of an overall environmental management system that has appropriate quality assurance and auditing that is consistent with ISO14000, the International Standards Organization's best practice manual. For ISO14000, an internal system is required that will ensure the external review/audit is passed. A critical tool is an up-to-date, site risk register, together with complementary action/project implementation plan, including responsibilities, costs and times, and details of staff training. The approach is designed to minimise risks and be a blueprint for continuing improvement.

PART III: TECHNICAL AND COMMUNITY REQUIREMENTS

Water is not only involved in all mining operations but it is a part of almost every stage of production. A conceptual flow model is used to illustrate the main functional elements of the water system and their organisation (Figure 7). This model is used to organise the technical leading practices and highlight the risks.

Figure 7. Conceptual flow model which lays out the components that must be managed to achieve leading practice outcomes.



Every operation is set within a surrounding environment and community (Chapter 6) and holds regulatory licence operating conditions which must be met. Many operations go beyond these compliance requirements in response to community concerns and/or corporate policies. Community relationships and environmental management can often go hand-in-hand. Managing these well can provide an operation with significant business advantages—particularly where the community is in a remote or regional location.

The site (lease) boundary is well-defined and provides the site interface to the surrounding community and environment. Regulatory compliance and production requirements determine the site water quantity and quality requirements around which the site water system is designed.

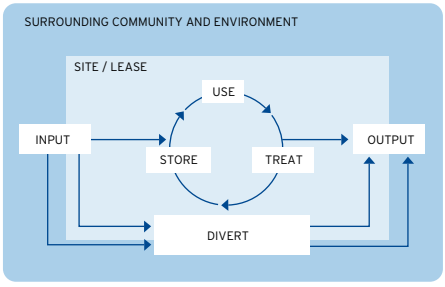
The water system is divided into four functional elements: (1) Input (Chapter 7): Delivery of water to the lease for operational use and/or diversion. (2) Use-treat-store (Chapter 8): This is the operational cycle of the site and includes the majority of management tasks associated with minimising losses, managing climate variability and implementing efficient technologies and processes. (3) Divert (Chapter 9): Moving water around or through the lease so that it does not become part of the operation. (4) Output (Chapter 10): Removal of water from the lease sourced from diversion and/or operational management.

The risks associated with managing the tasks and infrastructure for each of the functional elements and surrounding systems makes up the core of this handbook.

6.0 SURROUNDING COMMUNITY AND ENVIRONMENT

KEY MESSAGES

- Water management operates within a local catchment context to plan and manage the shared resource.
- Mine management should take into account the sensitivities of the regional environment and community, and ensure that mine water systems are designed and managed in to ensure that a balanced, sustainable outcome is achieved.
- Leading practice sites consistently operate beyond compliance in environmental protection and community engagement.
- Environmental flows and biodiversity are increasingly important, particularly where climate shifts are creating uncertainty in the prevailing hydrological conditions.



Water is a shared resource between users and the environment today and in the future. This chapter describes the implications of resource sharing in the context of communities and environments that surround operations. Leading practice operations have water efficiency targets and supporting action plans which demand that site water inputs are a focus for attention. Water is an asset with social, environmental and economic value. Increasing publicity surrounding water allocations across Australia, awareness of the consequences of extreme water-related events (drought and flooding) and discussion on climate change has focused community attention on water availability and where and how it is used. Legislative and voluntary changes to the management of water have also included the formal recognition of the need to provide water for environmental purposes.

Use of water by the minerals industry in Australia is small about three percent: ABS 2004) in the context of total consumptive water use. However, in certain situations mining can be a significant user of water and/or have significant impacts on local water resources. The community's perceptions of the mining industry use and impacts on the water resource require recognition and attention. A framework is required for reconciling competing demands such as agriculture, domestic water supply, environment or recreation. In many

instances this is primarily dealt with via markets in formal water property rights and development of water sharing plans as per current national and international policy priorities. However, cases exist where values associated with water cannot be dealt with simply through a water market (see Moran 2006 and Evans et al. 2006 for elaborations on this issue).

6.1 Community

Access to water is a fundamental human right. The communities within which industry operates, or impacts upon, expect and demand that: (1) they be involved in decisions regarding the allocation of water resources, (2) industry uses water efficiently, and (3) industry does not negatively impact on water quality.

Traditionally, community and other stakeholder consultation has been undertaken during the environmental assessment and project approval stage. Engagement with local catchment management authorities and other stakeholders during development and review of catchment water sharing plans should be sought. The dialogue around water use and allocation has had to deal with allocation of a scarce water resource between competing users. On a purely value-adding criterion (dollars generated per megalitres of water used), mining and minerals processing adds significantly more financial value per volume of water consumed than all agricultural uses (ACIL Tasman 2007). Under certain conditions in some jurisdictions water markets or contracting arrangements can be over-ridden to enact a hierarchy of use which includes domestic or town water, the environment, stock water, agriculture and industry. In the more remote areas, where the economic competition for water may not be as direct when compared with those operations in close proximity to urban areas and agricultural enterprises, the cultural and environmental values of water can be significant drivers. Sites may have opportunities to contribute positively by working towards maintenance of values.

Many examples exist where mines provide water to community members. This can range from stock and domestic uses to formal supply of larger volumes for irrigation through infrastructure designed, constructed and managed by the mining company. For example, the Bingegang pipeline in Central Queensland supplies many stock and domestic users along its path of several hundred kilometres. Cadia Valley Operations manages onsite raw water storages to ensure downstream flow targets are met to supply agricultural needs (see Case Study). Water supply can also be part of agreements associated with dewatering (see Section 9.4). This can occur through 'make good' agreements connected to changes in hydrological conditions caused by the mine.

Prior to, during, and post operations there is a need to understand the community environment—how water is used, who uses the water, seasonality of use, and existing and future stakeholder and community demands. Ongoing dialogue helps these communities understand the mine's water needs and for the industry to understand community expectations when making business decisions involving water use. Few communities

surrounding mines will have an intuitive grasp of the concept of mine closure. Therefore, it is particularly important that this concept is explored with the community early in the operation and that closure planning involves community throughout. This will minimise long-term legacies with communities over unrealised expectations post closure.

Community consultation and engagement techniques are discussed in the Leading Practice Sustainable Development Program's *Community Engagement and Development* handbook (www.ret.gov.au/sdmining). Given the sensitivity of water for livelihood, environment and cultural support, a great deal of community engagement is likely over water-related issues.

CASE STUDY: Water and the community—a need for early engagement

Iluka recognised in the initial planning stages for the development of operations in the Murray Basin that water would be an issue requiring extensive stakeholder engagement and agreement. Without early consultation, the current operations could have been severely disrupted by a lack of water due to drought conditions.

The mineral separation plant (MSP) in Hamilton, Victoria uses reclaimed waste water which is sourced from a purpose–built, ultra-filtration membrane plant located at the Wannon Water facility, east of the MSP. It has been designed to produce 0.82 megalitres per day of reclaimed water. This idea was generated as a result of discussions with community members and regulators who were concerned about a reduction in the town's scheme water. The treatment plant produces water in excess of Iluka's needs and has the potential to benefit other industries and further reduce scheme water reliance.

The process water for Iluka's Douglas mine site which supplies concentrate to the MSP was originally sourced from the Rockland Reservoir which is part of the Grampians Wimmera Mallee Water Authority supply system. This is delivered to Douglas via piping to reduce evaporation, but due to drought conditions in recent years, Iluka has sought community involvement and support in identifying alternative water sources. This has led to the Grampians Wimmera Mallee (GWM) Water Authority agreeing to allow Iluka to commission a borefield adjacent to the pipeline to supplement mine process water and reduce dependence on the Rockland reservoir. This bore field was discovered by Iluka in an area that was not known to contain water. An additional borefield initially funded by Iluka near the Grampians now provides additional security to Horsham City's water supply and ensures adequate water supplies to the residents during times of drought. In exchange for the installation of this bore, Iluka was granted additional prorata allocation rights to water sourced from the reservoir system if required. Internal initiatives such as improvements in water collection from tailings and using evaporation reduction processes further reduces the need to impact on existing external water resources in the region.

Iluka has supported the community during drought periods by installing water storage tanks at sporting facilities and supplying stormwater runoff carted from the Douglas mine site; arranging for stormwater collected at the MSP to be used on Hamilton sporting fields; and the installation of a fire hydrant off the reservoir pipeline at a road junction to support the Country Fire Authority during emergencies. These initiatives develop goodwill within the local communities and help maintain the mine's social licence to operate.

Illuka Resources engaging with the local Murray Darling Basin community.

image Source: Illuka Resources

6.2 Cultural heritage

Cultural heritage places are integral to Indigenous Australia's connection with their traditional lands. Therefore any successful relationship between a mining company and an Indigenous community will include recognition and respect for the community's cultural heritage.

Many examples exist where operations engage with local Indigenous communities to manage issues of cultural concern that are not strictly dealt with as a legal requirement under the *Native Title Act* (see Section 2.3). These arrangements can be wide ranging and often need to be locally sensitive due to the local traditional importance. For water, such arrangements often surround the protection of water courses or water bodies of cultural significance and/or the ecosystems that depend on them.

For more information on cultural heritage, see the Leading Practice Sustainable Development Program's *Working With Indigenous Communities* handbook (www.ret.gov.au/sdmining).

6.3 Environment

6.3.1 Understanding the water cycle and catchment values

Mining operations occur in a wide range of environments across Australia including wet/dry regions with strong or weak seasonality and large variation of conditions. Mining operations require a reliable and consistent water supply which in highly seasonal climatic conditions could require additional water licences, bores or storages. The nature of mining requires operations to manage this variability in environmental conditions. For example, mining below the water table in an arid area requires the continual dewatering of the operational area and the diversion (possibly with temporary storage) of this water to the environment.

The Leading Practice Sustainable Development Program's *Biodiversity Management* handbook (www.ret.gov.au/sdmining) discusses many of the aspects of managing biodiversity which are equally relevant in the water context.

Key to managing environmental water requirements is the understanding of temporal dynamics. Mines tend to require a more-or-less constant water supply whereas the relationship between climate and hydrological variability and environmental dependence is more dynamic. Therefore, it is necessary to consider the environmental requirements of groundwater-dependent systems, for example, as well as those catered for under river environmental flow consideration (see below).

Mining results in permanent changes to the landscape which can alter its hydrological function. This, in turn, may have significant long-term consequences for the surrounding environment following closure. Leading practice operations plan and construct final landforms (their shape, geochemical and geophysical attributes) with a view to minimising the long-term impact of the mining operation. A whole-of-mine-life planning and implementation strategy is required to effectively achieve this. Leading practice water outcomes from final landforms cannot be achieved by manipulating the landscape only after mining ceases.

6.3.2 Environmental flows

An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation (IUCN 2003).

As a result of the 1994 Council of Australian Governments (COAG) review of water resource policy in Australia, a set of national principles for the provision of water for ecosystems was developed (ARMCANZ & ANZECC 1996) which set the goal for providing water to the environment as being "*to sustain and where necessary restore ecological processes and biodiversity of water dependent ecosystems.*" Australian states and territories have interpreted the reform principles differently, resulting in multiple methods for determining

environmental water requirements. A comprehensive description is contained in a series of LWRRDC Occasional Papers from the project '*Comparative Evaluation of Environmental Flow Assessment Techniques*' (Arthington et al. 1998a & b, Arthington 1998 and Arthington & Zalucki 1998). The eWater CRC developed a program called the River Analysis Package (RAP) for environmental flows assessment. RAP can be freely downloaded from www.toolkit.net.au and would, normally, be used in conjunction with hydrological models.

Management of water on a mine site may alter key flow characteristics of downstream water courses. This can occur by:

- causing extended and/or elevated base flows due to relatively constant discharges, for example from mill operations or dewatering;
- time shifting of rainfall-runoff flows and attenuation of flood flow peaks such as by capture of site runoff and treatment in retention ponds;
- reduction in site runoff, for example by use of a zero-release strategy or enhancement of onsite evaporative losses of water from potentially contaminated areas;
- increasing flood flow peaks and reducing base flows by reduced infiltration and/or increased runoff rates resulting from removal of natural vegetation and soil covers of areas or compaction of soils and subsoils;
- disruption of existing relationships between surface and groundwater systems;
- diversion of waters from one catchment to another;
- altering the physical, chemical and/or biological characteristics of the water in flow events; and,
- converting temporary waters to perennial waters or vice versa.

Leading practice management of the flow impacts of water discharges from a mine site should be compatible with the relevant legislative frameworks as well as taking into account the environmental flow objectives that have been determined for the impacted catchment. Conversion of an ephemeral stream to a perennial stream as a result of ongoing discharges of mine water (for example, from dewatering operations) will result in disruption of the natural ecological processes that depend on seasonal variations in flow.

Temporary waters often have random recruitment into each water body upon filling, and regional biodiversity may be reliant on there being a mosaic of temporary waters that provide critical dry season refuges. Establishing an unnatural perennial flow regime could result in reduced biodiversity at the local scale (by promoting only the species that tend to dominate in perennial waters) and at the regional scale (by reducing the number of temporarily inundated water bodies). Establishment of perennial flow in a naturally ephemeral stream or river can also profoundly change the composition of the aquatic and riparian vegetation—such that the riparian zone becomes dominated by species that require year-round water. When flow ceases at the end of the discharge period (which can, in some cases last for many years) there will be dieback of the riparian vegetation, resulting in destabilisation of the banks and increased erosion. In this circumstance rehabilitation of the stream banks may be required.

Changes to flow regime may also increase the risk of establishment and spread of invasive species such as aquatic and terrestrial weeds, which may result in long-term management requirements.

Whether or not any of the above outcomes resulting from changes in flow are acceptable or not will depend on the implications in the catchment and, in particular, any sensitive, rare, threatened or endangered species or communities that rely on the natural water cycle.

Leading practice always considers the broader implications for the receiving catchment, even if compliance is achieved at a point specified in a mine's operating authorisation. Passage of aquatic organisms (e.g. fish) through watercourses can be inhibited or prevented entirely by chemical barriers caused by poor water quality (Smith 2001). Considerations for physical barriers are equally relevant to chemical barriers, but the issue for discharges is that even a short section of poor water quality in a stream resulting from a point-source discharge may have broader implications if movement to other parts of the catchment is inhibited. This could occur where the mixing zone covers the full stream width, even if water quality complies with the discharge licence conditions outside the mixing zone.

CASE STUDY: Environmental flows Cadia Valley operations

The Cadia Hill gold mine was approved on 6 September 1996 with several conditions imposed. These conditions related to the release of water from Cadiangullong Dam and the maintenance of flows in Cadiangullong Creek to provide environmental flows and as well meet the requirements of downstream users.

Limited baseline data on the aquatic ecology and hydrology of Cadiangullong Creek was available at the commencement of the project and additional data was collected as part of the environmental impact studies. At the time of the construction of the Cadiangullong Dam, empirically based processes for determining the riparian and environmental flows needed to maintain riverine ecosystem integrity were in their infancy in Australia. Virtually no research had been undertaken on these issues in small upland streams.

Applying the Montana Method and using the flow criteria developed by Tenant (1976), it was concluded that a minimum survival flow for maintaining 'fair' aquatic life would be >10 percent of mean annual flows or about 3.3 megalitres per day at the confluence of Cadiangullong and Cadia creeks and 3.9 megalitres per day in the Cadiangullong Creek at Panuara Road.

The flow conditions which were designed to maintain the environmental health of Cadiangullong Creek as well as taking into consideration downstream users, included:

- when flows into Cadiangullong Creek Dam are between 0.4 megalitres perday and 3.4 megalitres per day, water shall be released from the dam such that is equivalent to the inflows into the dam is released from the dam;

- when flows into Cadiangullong Dam fall below 0.4 megalitres per day flows at the boundary of the mine lease area shall be at least 0.4 megalitres per day;
- all high flows passing over the spill way will be maintained; and,
- water releases will be made of up to four medium flows (between 12 and 15 megalitres per day) per year, each for one to three days, with timing and frequency of flows determined by hydrographs of typical medium flows.

Cadiangullong Creek Dam. Image Source: David Parry, Charles Sturt University

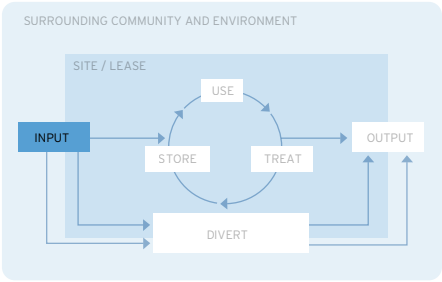
Additional research was required to be undertaken to assess and model the effects of changing flow regimes (drought, low, medium and flood) on in stream and riparian environments and their associated organisms. The Environmental Studies Unit at Charles Sturt University was contracted by Cadia to design and carry out appropriate research to satisfy the requirements of this condition. The researchers concluded that there was no evidence of a decline in stream diversity and that under the range of flows available during the study period, a very high level of family diversity was maintained (Herr et al. 2004).

7.0 INPUT—SOURCING OF WATER

KEY MESSAGES

- Monitoring, control and understanding of water input to a site allows the site water system to be proactively controlled and managed without surprises.
- Input management to the site is necessary to provide certainty over water security and to avoid unnecessary releases due to over-filling.
- Security of supply is balanced against the impact on the source environment and community.

Input: The tasks and infrastructure associated with managing water input at the interface between the operation and the surrounding environment. The boundary of this interface includes the lease (via pipelines, channels and rivers), underlying aquifers (via bores and dewatering) and the atmosphere (via rain interception). There are two main functions for input tasks:



1. supply of water for site operations (source for the use-treat-store loop).
2. source of water that will be diverted around or through the operation.

The main tasks involved in input are supply identification and verification; design, construction and management of the water supply system (pumping, pipeline and bore field control and maintenance); and control of mine dewatering activities (including optimising with respect to the mine plan).

7.1 Key risks

Security of supply: Lack of supply (quantity and reliability) may result in production losses and the possible need to downsize operations with serious consequences for staff and local communities. Security of supply is controlled by understanding the level of certainty over the water source and the site water demand.

Effect on source environment: Inappropriate abstraction/diversion of water resources will have unacceptable consequences to the source environment, reducing long-term supply availability.

Water quality variation: Unacceptable water quality from the source may jeopardise operational efficiency, such as mineral recovery, or make it difficult to divert or release water. Inappropriate supply management strategies may lead to significant changes in water quality.

Oversupply: If too much water is brought into the operation, storage capacity may be exceeded resulting in unregulated releases. In addition, if dewatering rates exceed diversion infrastructure capability production may be stopped.

Under supply for diversion: If dewatering does not produce water at expected rates, agreements over diversion rates, such as environmental flows, may not be met.

Corporate targets: Water input is the control point for meeting corporate targets for water withdrawals from the environment.

Meeting expectations of other users/competitors: Many operations supply water to other users through their infrastructure (stock and domestic users supplied along a pipeline) and/or access arrangements (management of bore fields). Failure to meet these expectations can result in legal challenges and/or damage to community relations which may have implications across the operation. Any arrangements over water access or supply that exist during the operation must be negotiated for closure or significant community threats may arise and/or opportunities lost. Opportunities exist when raw water is made available when an operation shifts to a fit-for-purpose reuse source and/or recycling is undertaken.

Meeting community expectations: The surrounding community often has expectations about water inputs regardless of their reliance on the operation. Raised awareness of the true value of water places increased importance on community relations with respect to water abstraction. Unmanaged expectations of water access following closure can result in significant community unrest.

7.2 Leading practice control of risks

Leading practice for controlling these risks requires that:

- the water demand for the operation, over its life cycle, is robustly established, including consideration of climate and hydrological variability;
- dewatering rates are determined with quantified confidence limits—ultimate accuracy will not be possible at the design stage but design should incorporate sensitivity analysis of possible variation;
- the site water system is designed to optimise against the constraints of the capacity of the supply environment, reasonable costs and corporate efficiency requirements;
- water quality tolerances/requirements for each operational component of the site (water task) should be defined and recorded in the water management plan and appropriate management responses to any changes to these conditions documented in the operational procedures;

- all licence, statutory requirements and water allocation processes and rules for the region should be understood, particularly water security probabilities, and recorded in the water management plan. Understanding the water supply hierarchy and how it dictates use to other uses as a priority in times of scarcity and/or emergency;
- the capacity of the source environment to sustainably meet the demand, including requirements for environmental flows, is well understood and the design and operating parameters of the water management system ensures that this capacity will not be exceeded; and,
- the responsibilities of the operation for meeting demands of other water users are recorded in the site water management plan and are not only communicated to the operators of the water management system, but are made part of their performance agreements. This must include plans for post-closure relinquishment of any infrastructure that will remain in place to support community water needs into the future. Where there is to be no infrastructure remaining, the community must be made aware that it will lose access to any water that was previously supplied and/or it felt may be available in the future.

7.3 Demand and design

Leading operations quantify the water requirements for the life-of-project within reasonable limits of confidence. As the operation progresses more information will become available and the water management plan and operating procedures (see Chapter 4) should be updated accordingly. Leading practice ensures that water availability in the physical, economic and social domains is taken into account when the operation's water system is designed. In many cases, the project team is given the operation's technical specifications and requested to find the necessary water. This is not leading practice design. Cases exist where design can be used to embed options that may be triggered in the future if needed.

CASE STUDY: Pre-investment in sea water cooling (Yarwun)

Investment in preparatory capital works in cooling towers in the new Rio Tinto Aluminium Yarwun alumina refinery, will allow a more rapid and less expensive switch to seawater cooling should the need arise in the future.

Context: During the 2003 drought conditions experienced in Gladstone, one of the crisis options being considered by the existing Queensland alumina refinery was to retrofit seawater cooling to its cooling towers, which consume a significant proportion of the refinery's fresh water intake. Seawater cooling is generally more expensive due to the high capital requirements for stainless steel piping and pumps. This option was shelved when a cyclone replenished the local water source at Awonga Dam. However,

in constructing a new refinery in Gladstone during the same period, Rio Tinto Aluminium considered the prospect of a similar occurrence, and the alternative scenario of increasing water prices made seawater cooling more cost-effective than the use of fresh water.

Rio Tinto Aluminium Yarwun alumina refinery. Image Source: Rio Tinto

Decision processes: An option was identified requiring a modest (<$2.5 million) capital investment to fit the required equipment to the critical parts of the cooling tower facility. This significantly decreases the lead time required to make the switch to seawater cooling should the need arise, and also ensured that there were no plant layout issues associated with such a 'retrofit'. Given the size of the expenditure, this was approved at the RTA Management Team level. The investment was justified using risk-based arguments centred on the security of water supply.

Valuation issues: The value in this case is contingent on uncertain future events. The investment will not realise a positive net present value (NPV) result unless seawater cooling is invoked. However, option analysis recognises the ability to switch inputs as a source of value in the face of uncertainty, making the facility more resilient to changes in the external environment. In this case the sources of uncertainty include both the availability and future pricing of fresh water in the Gladstone region.

7.4 Resource quantification

Quantification of groundwater and surface water resources always includes uncertainty due to climatic and hydrological variability. This uncertainty is compounded by constraints of budget, time and the impossibility of 100 percent certainty regardless of time and budget. To minimise the risks associated with uncertainty:

- groundwater modelling should be based on adequate exploration bores and test pumping exercises so an experienced hydrogeological modeller can estimate valid parameters and boundary conditions;
- surface water catchments should have adequate hydrological gauging prior to project development to provide sufficient data for water yield modelling. Without this data, generic hydrological parameters must be used which creates greater uncertainty;

- wherever possible, rainfall information should be based on local monitoring. Data can be statistically generated for all locations in Australia for application in stochastic hydrological models; and,
- all data should be collected from the earliest stage possible—beginning with exploration. Similarly, implications of changes to the local water system following closure should be dealt with well in advance of closure.

A key risk to manage in quantifying resource availability is meeting environmental and community requirements (Chapter 6). For example, if a mine assumes that water can be taken at a constant rate and recharge is periodic, ecosystems that depend on the groundwater may be compromised even though investigations indicate that the aquifer still contains large volumes of water.

Ongoing monitoring should be used to update model calibrations and predictions as more data become available. Adequate forecasting requires the consideration of the range of likely climate conditions. With uncertainty due to climate change, leading practice sites are modelling a wider range of conditions to understand and limit associated risks.

7.5 Integration of water supplies

Leading practice dictates that supply of water to even a single component/process within the operation must be considered in a holistic way. The site operational simulation model with linked water quality requirements and constraints is the best tool for analysing options. The need for additional draw on new water resources outside of the existing water circuit needs to be fully justified. This includes a cost analysis and consideration of life-of-mine requirements. Integration provides significant synergy and opportunities, while short–term, single-user solutions may become long-term liabilities. It recognises the full range of water types available for use on a site as illustrated in Table 4. In some cases, it is possible to reduce overall water consumption by integrating sources from nearby mines. Redirection of groundwater from mine operational dewatering at one mine rather than continuing to extract from a separate borefield at another is an active development in a number of Pilbara iron ore mines, for example, Paraburdoo and Mt Whaleback (see case study).

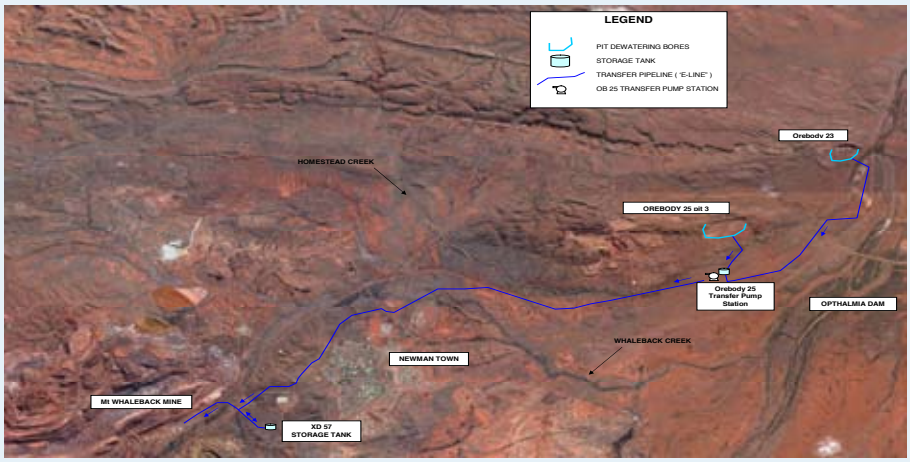
Integration of the operational water supply system within the regional supply system provides benefits. In Weipa, selective use of different water sources has improved water security, reduced costs through increased reuse and benefited the reputation of the operation (see case study). In other situations, such integration offers increased efficiency and opportunities in terms of water trading, particularly with respect to waters of differing quality. For example, the cost of plant modifications to use poor quality water may be off-set by gains in trading good quality water entitlements to other users. Similarly, water sharing arrangements between adjacent mines may reduce the burden on one to dispose of excess water, allow the second to access the worked water and thereby potentially free up fresh water for other uses in the catchment. For example, this type of approach is increasing in application in the Hunter Valley in NSW.

CASE STUDY: BHP Billiton Iron Ore Mt Whaleback and satellite ore bodies' water supply system

BHP Billiton Iron Ore manages two satellite ore bodies, Orebody 23 and Orebody 25 situated approximately 12 kilometres and eight kilometres to the east of Newman and the company's Mt Whaleback operation.

Mining of both ore bodies requires lowering of the water tables through the use of dewatering bores.

The Mt Whaleback mine west of Newman has a large process water demand. Rather than develop local groundwater sources which would potentially be lower cost, the dewatering water from Orebody 23 and Orebody 25 Pit 3 is pumped about 13 kilometres and against a static head of 90 metres to a storage tank which then provides a gravity supply of process water.



Topographical map showing Mt Whaleback water supply system. Image Source: BHP Billiton

By utilising the dewatering water across this interconnected system between Orebody 23, Orebody 25 and Mt Whaleback, the overall groundwater abstraction is minimised, reducing the impact from mining operations.

The dewatering system at Orebody 23 and Orebody 25 comprises a total of 19 bores. Abstracted water is piped to Orebody 25 transfer pump station for delivery to Mt Whaleback for process water use. When the transfer pump station tank is full, water is discharged to the adjacent Ophthalmia Dam facility where the majority of water recharges the aquifer being dewatered, albeit at a distance from the dewatering bores, to minimise recirculation. The transfer tank, pump station and bores are automated and a telemetry system has been installed. The status of the bores and transfer tank, together with flow rates and tank levels, are remotely monitored and recorded at the Mt Whaleback control room.

CASE STUDY: Development of a water source hierarchy (Weipa)

An operating hierarchy which determines which of the potential sources of water the mine will draw on has been established at Weipa.

Context: Bauxite mining operations at Rio Tinto Aluminium Weipa occur in a region of water excess, due to the tropical and monsoonal climate. The mine has multiple sources of water to draw from, each of which has its associated costs and additional values. The four main sources are decant water from the tailings dam; site rainfall runoff captured in 'slots' and other small storages across the mining lease; shallow aquifers underlying the area; and the deeper aquifers of the Great Artesian Basin. Availability of the different sources can vary during the year, particularly the first two sources.

Bauxite mining operations and port at Weipa, Queensland. Image Source: Rio Tinto

Decision processes: The sensitivity of the shallow aquifers and the Great Artesian Basin has previously been identified during normal environmental risk management processes. This has been reinforced by engagement with key stakeholders, including the Great Artesian Basin Coordinating Committee and the Wilderness Society. The latter has focused particularly on the connectivity that can occur between the shallow aquifers and local rivers. These processes have resulted in the establishment of a formal hierarchy of sources, directing the operation to source first from tailings dams, then 'slots', then the shallow aquifers, and finally the Great Artesian Basin aquifers.

Bauxite Stockpile at Weipa, Queensland. Image Source: Rio Tinto

Valuation issues: In general, the costs associated with sourcing from tailings dams and slots are less than those arising from operating borefields fed by underground aquifers. However, due to the large area of the mining lease, there are situations where it could be cheaper and more convenient to source from underground aquifers. The establishment of the sourcing hierarchy effectively places an implicit value on the natural sources of water. In the case of the Great Artesian Basin, the focus is on the long-term sustainability of the resource as it has a slower recharge rate. The shallow aquifers recharge more quickly due to the climate, but can be linked more closely to the river ecosystems.

7.6 Supply cost considerations

The majority of Australian mines rely on surface and groundwater resources located close to operations. However, there are those that rely on water transported great distances through extensive pipeline networks. The cost of supplying this water can be significant yet it is often not fully accounted for. As water is used across all processes in an operation there is a tendency by management to absorb most water-related costs as a site overhead. The danger of this approach is that the true operating cost for individual processes/activities is never known, eliminating a key driver in water use efficiency programs.

Leading practice means that water supply cost considerations not only incorporate borefield development, storage reservoir construction and conveyance networks costs, but also account for the economic impacts on other parties and organisations, as well as non-financial social and environmental impacts. Evans et al. (2007) provide details on how such costs may be modelled using an input-output or cost benefit analysis.

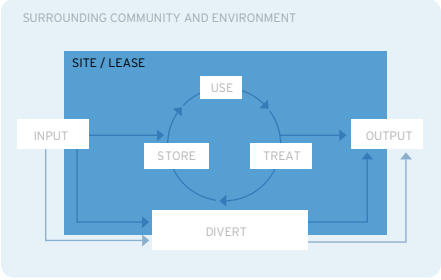
Cost liabilities associated with post-closure arrangements for supply of water to communities should be fully costed to ensure the company is aware of the full extent of any liabilities.

8.0 USE-TREAT-STORE: TECHNICAL WATER MANAGEMENT

KEY MESSAGES

- Leading practice water management is effective management of water storages, tasks (operations uses) and water treatment plants.
- Integrating the correct people across technical areas into a site water management team is critical to achieving leading practice.
- A strong and up-to-date connection between day-to-day decision making, strategic planning and the site water management plan is essential.
- Water-related issues may persist long after mining ceases. Design, implementation and management of leading practice water management systems are carried out from the earliest stages of exploration with a view on closure.
- Storage management is key to ensuring water release and water scarcity are controlled.
- Effective management of the water associated with waste rock dumps and tailings facilities are critical to leading practice.

This chapter deals with the majority of operational management of water.



Use: Use refers to the operational tasks that involve water. This includes all the tasks that are not part of input (Chapter 7), divert (Chapter 9) or output (Chapter 10). The full set of tasks will depend on the particular operation. Tasks include but are not restricted to:

Product separation/crushing: Water is used to separate product from non-product (waste rock/coarse rejects and gangue for metals, ash or non-combustible material for coal) in mined materials. Few fully dry minerals processing facilities operate in Australia.

Solid non-product (waste) handling, transport and storage: Non-commodity materials include tailings, coarse rejects and overburden. These are stored in purpose-built facilities and mined pits.Coarse materials, in particular, create significant permanent landscape hydroecological changes.

Product moisture control: Product moisture must be controlled to meet transport and client specifications.

Wash down: Plant and equipment wash down is part of ensuring the life span is not shortened due to poor performance and/or corrosion.

Potable water uses—drinking washing, showering.

Infrastructure design, construction and maintenance.

Treat: Treat refers to any process that is employed on a site to change the quality of water or its use. It can range from sediment stilling ponds to sophisticated filtering, dosing and reverse osmosis plants.

Store: Stores are the facilities on a site which hold and/or capture water. They are the internal supplies for tasks and must supply all water that is not sourced from 'input' in a given timeframe of demand.

8.1 Key risks

- **Product recovery compromised:** If water quality and/or quantity do not meet fit-for-purpose specifications in product separation, recovery may decline. The implication is lost revenue and/or difficulties associated with managing worked water or finding enough raw water when raw water is taken by preference.
- **Infrastructure does not operate to specification:** Compromises can occur to production, environmental compliance or community relations in a wide variety of locations in the operation. This can cause down time, expensive late maintenance and loss of community support for the operation.
- **Incorrect infrastructure implementation:** Poor use of reticulation standards can result in contact or consumption of water by the workforce. Over-capitalisation of infrastructure can result in loss of confidence in decision makers for appropriate future investments.
- **Stores collect more water than expected:** Excess water must be released. Corporate targets may be compromised.
- **Stores collect less water than expected:** Insufficient water to meet demands. Corporate targets may be compromised.
- **Stores lose more water than forecast:** As above.
- **Store geotechnical failure:** Failure of stores can lead to catastrophic consequences, including loss of life, down time, serious environment incidents.
- **Store water quality:** If water quality in stores is not managed, for example, toxic blue-green algae appear, then consequences can include workforce exposure, downtime due to unfit water and mineral recovery losses. Water release plans may be compromised.

- **Non-product storage facilities:** Release of contaminants, such as acid, metals, organics, salt, may cause short term environmental and safety incidents. Long-term consequences of poorly operating waste rock dumps, tailings facilities, are reputation damage and threats downstream community health and/or livelihood.
- **Ineffective monitoring:** Ineffective monitoring may result in unexpected water system performance with down time, safety, health and community consequences.
- **Water management teams not integrated:** Poor integration of water management team can result in down time, accidents, inability to meet release plans and community expectations.
- **Closure legacies:** Inability to achieve final mine completion and relinquishment due to ongoing water management issues such as seepage and acid mine drainage from mining-related landforms can result in the need for water treatment in perpetuity.

8.2 Leading practice control of risks

Leading practice for controlling these risks requires that:

- effective planning is carried out at a catchment level including strategic water option analysis for life-of-mine. Critical to this is a clear understanding of the importance of final landform in determining and effectively managing the long-term issues associated with water. These considerations include final voids and non-product landforms (fine residuals and rocks);
- water inputs, losses, outputs and changes in storage are monitored with sufficient precision and within time frames required for operational decision making;
- maintain a whole-of-site water management team that regularly reviews the water management plan and operating procedures;
- non-product storage facilities are designed and constructed for the very long term;
- water reuse requirements to meet fit-for-purpose expectations are met; and,
- optimise onsite water recovery and minimise water losses.

8.3 Site water use

Water is used for numerous tasks across the mine site and will depend on the type of operation. Section 8.1 outlines the main water use tasks and Table 4 summaries the principle sources and types of water. Leading practice mines minimise water use while maximising water reuse.

8.3.1 Water Reuse

Water reuse is defined in a number of ways and is also often used interchangeably with water recycling (see text box for explanations). Water reuse minimises demand for water from off site and thereby focuses attention on leading management practices within the site. Leading operations generally have better control over water releases (Chapter 10) because reuse is carried out extensively and consistently.

CASE STUDY: Olympic Dam water savings project delivers a sustained change

Aerial Photo of Olympic Dam Processing Plant. Image Source: BHP Billiton

Olympic Dam recognises that the responsible use of Great Artesian Basin (GAB) water is essential to protect the environmental values of the GAB springs, a key concern for some of our stakeholders.

We monitor the rate at which we extract water from the two wellfields to ensure that we are always within prescribed limits and that adverse impacts are not occurring. Our ongoing challenge is to continue to meet these limits while providing the opportunity to optimise plant production rates.

A key to meeting this challenge is to improve water use efficiency in line with the BHP Billiton's Sustainable Development Policy.

A dedicated team was created to assess:

- Current industrial water use volumes and purposes.
- Particular process streams and plant areas with substantial increases in production-based water consumption.
- The potential for reductions through increases in efficiency, recycling and reuse of process streams.

A series of water use maps, including numerical balances and comparisons of both current and historical data, was created for the concentrator, hydromet and smelter plant areas.

Water savings projects were then identified through discussions of water map data with area personnel or suggestions from area personnel.

The project confirmed the importance of regular inspection, testing and calibration of process indicators. Significant water savings have been identified and implemented in the three key production areas.

For further information on this case study see http://bhpbilliton.com/bb/sustainableDevelopment/caseStudies/2007/olympicDamWaterSavingsProjectDeliversASustainedChange.jsp

If water has to be treated it is considered as recycling not reuse. Therefore, water reuse is desirable because it only requires energy and infrastructure to transport the water and is a direct replacement for water that would otherwise have to be imported. Leading operations understand that the business case for investment in such infrastructure and energy must acknowledge a range of values of water.

An important feature of managing operations with large reuse levels is the concentration of potential contaminants. This can occur though accumulation and concentration due to evaporation. Accumulation can be due to the constant additions from a source (minerals concentrator reagents) or from interaction with site water facilities (stores subject to algal blooms). Therefore, it is necessary to understand how the site water system interacts with the water upon repetitive recirculation. Equally, any concentration constraints to use of the water for particular functions must be well understood and incorporated into site water management plans and operational procedures.

Defining water reuse and recycling

Water reuse reflects the relationship between how much water is used in an operation and how much is imported. It is the relationship between worked water on site and imported water (which may be raw or from another worked source, such as another mine).

Water reuse can be expressed in one of two ways depending on the user of the information. In both cases reuse includes recycling (see below).

Intensity of importation:
Water reuse = worked water / water input

Proportion of total demand:
Water reuse = worked water / (water input + worked water)

In both cases, the reuse is computed over a stated time period (often a year) and worked water is the total flux of worked water. This means that the same unit of water can be used many times over the period. Therefore, the total worked water use can exceed the worked water stocks on the site.

In general, assuming production is more-or-less constant, imported water is a measure of the amount of water exported from the site either through losses (evaporation) or in the exported commodity either in pore space or as a carrier medium in pipelines.

A common way to differentiate reuse and recycling is adopted from material waste management. Reuse is when a material is used in a task without any transformation. For example, returning a glass bottle for cleaning and refilling. Recycling is when a commodity, such as an aluminium can, is reduced to its material composition, aluminium, and reformed into a commodity which may be the same as the original or different. The same convention applied to water indicates that reuse is when water is passed from one task to another on a mine site without transformation. Water is recycled when it is treated in one way or another before it is used in another task. Common forms of treatment are filtering of solids, neutralisation and desalination (see Appendix 1).

8.3.2 Waste (non-product) rock dumps

Waste rock dumps (or piles) are often a significant source of worked water at a mine site. The dumps can cover large areas of mine catchment which previously had established surface drainage patterns. Blanketing these sub-catchments with unconsolidated rock material creates a 'sponge-effect' in which rainfall infiltration becomes temporarily stored to be later released as groundwater recharge beneath the dump or surface seepage at the foot of the waste rock dumps. Initially, percolation through the waste rock pile to the foundation and from the toe of the pile along buried surface drainage channels will occur via preferred pathways, transporting any contaminants formed by the oxidation of waste rock. Most

percolation will occur in response to heavy rainfall events. Eventually, the waste rock pile will wet up sufficiently that there are continuous water pathways through the pile and any rainfall infiltration will be matched by percolation at the base of the pile resulting in a greater potential for contaminant transport. The time required to reach this breakthrough condition as a function of average rainfall can be estimated (Williams 2006).

Leading practice limits seepage and transport of contaminants by using water retention (store and release covers) and water shedding (engineered drains) designs. Leading practice in the former, recognises that real systems contain cracks and other macropores resulting in preferred flow pathways. Consequently, there may be considerable temporal and spatial variability in the hydraulic properties of the cover materials and their interface with the underlying rock mass. Store and release covers are generally placed on the flat surfaces of dumps, necessitating use of water shedding designs on the slopes/batters (up to half of the area). Outer batters need to be protected to avoid erosion and gully formation that could cut back into the underlying waste material. The occurrence of short duration, high-intensity rainfall which exceeds cover infiltration rates means that upper surfaces of a dump should be profiled such that runoff is directed away from the outer crest bund and channelled along engineered rock drains, ideally at gentle gradients to restrain flow velocities. This practice limits the volume of water flowing down a slope to that which arises from direct rainfall interception. The construction of a substantial crest bund is therefore essential as additional concentrated runoff from the top surface of a dump accelerates erosion. It is important to get the dimensions of step-backs and crest bunds right as material that erodes from the upper areas will progressively fill the void behind mid-slope bunds resulting in overtopping and accelerated erosion of the lower slope.

Figure 8. Outer slopes of waste rock dumps: (left) Bi-linear batter slope and (right) continuous concave batter slope.

The adoption at closure of a concave slope profile helps minimise erosion of the outer slopes (Figure 8). Concave slopes are formed from suitably sized and spaced step-backs during the dumping process which can later be reformed into a continuous slope.

The acid rock and metalliferous drainage aspects of waste rock dump management are described in the Leading Practice Sustainable Development Program's *Managing Acid and Metalliferous Drainage* handbook (www.ret.gov.au/sdmining).

8.3.3 Stockpile management

Leading practice operations control dust from stockpiles with sprays triggered by prevailing environmental conditions based on research into effective parameter settings. The size, shape and periods over which a stockpile is left in place may be in part determined by its water holding, percolation, and shedding properties. These are controlled to ensure that requirements for mineral separation, transport (truck, conveyor, train) and client commodity specifications are met and to assure a safe operating environment in and around stockpiles. Dust control is required at stockpiles off the mining lease including transport facilities and other mineral processing operations such as refineries and smelters.

8.3.4 Product Separation—concentrators

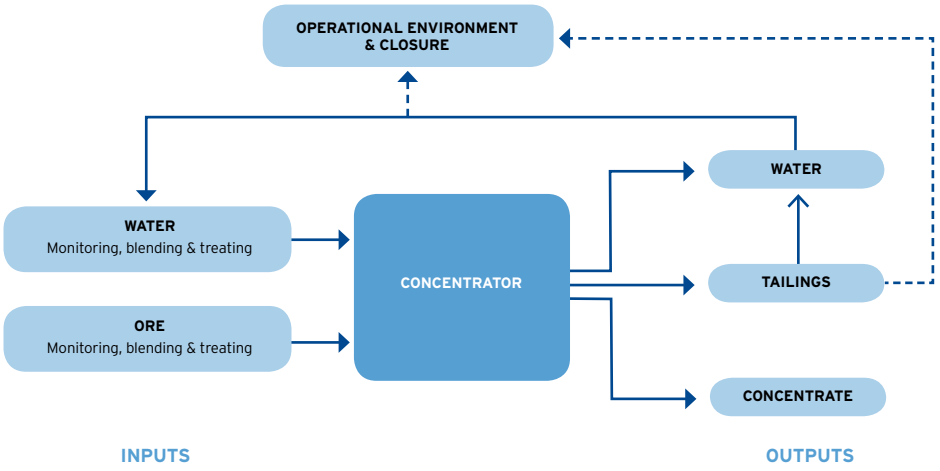
Many sites combine mining and mineral processing, cleaning or concentrating processes that require water such as ore concentrating, coal washing and iron ore crushing. Many of these facilities alter water quality—some minimally and others profoundly. Leading practice sites understand, plan and manage the water in and around the plant recognising it is part of a whole-of-site water system. Figure 9 provides a view of the flows into and out of a typical product concentrating facility. Water and ore/coal are the main inputs and water, tailings (possibly coarse reject materials) and concentrated product carry water from the plant.

Outside the plant, leading practice operators monitor water quality and treat where necessary to ensure it is fit-for-purpose (see Section 8.4). Leading operations also monitor the ore feed to ensure that any likely interactions between changes in ore quality and water quality are understood. Problematic water quality should be dealt with external to the plant if possible, for example, through blending water sources. If this is not possible leading operations ensure there is an effective communication channel from those controlling water supply to the plant to ensure plant controllers can respond inside the plant accordingly.

Plant operations: Inside the concentrator, the most important aspect of leading practice is to ensure that plant operators are responding to variations in water, ore and other operating conditions in an agreed manner. Experience indicates that many plants suffer from 'over tuning' based on operator intuition rather than plant monitoring feedback and standard operating protocols. It has been demonstrated (Mt Isa lead-zinc concentrator) that this sort of approach affects operating performance, reagent consumption and increases the effort to have efficient water returns. Leading practice sites have continuous improvement processes to ensure that operating myths do not become confused with leading practices. Plant maintenance to ensure operating conditions are as per specifications is vital for maintaining process efficiency. Effective management of water returns, including from tailings facilities,

includes monitoring quality and ensuring blending is used wherever possible to minimise treatment requirements/costs.

Figure 9. Overview of the flows into and from a mineral concentrator (or coal washery or iron ore crusher) and the main management issues for leading practice.



Water input sources: Leading practice plants return as much water with beneficial properties as possible. For example, tailings water and returns from clarifiers and other unit processes are likely to contain unused reagents such as flotation frother. The second priority is to try to find water from the site that is known to be clean or, at least, of known and manageable quality; that is, it can be used without compromising plant, minerals recovery or other site water management requirements. An important feature of achieving this is communication between various parts of the site. For example, if the underground mine is to dewater an area with water of a different quality to the average (containing gels or high sediment loads), and this is not communicated to the plant, significant recovery losses may occur. If this happens on a number of occasions it can become increasingly difficult to ensure that site water reuse is optimised. It is human nature for the plant operators to prioritise use of clean water over use of other site water to avoid operating glitches.

As a last resort, water that is available but not fit-for-purpose can be treated. Clearly, this is less attractive than reuse or sourcing from other parts of the site but may be necessary to fully control a process and/or secure certain supply.

Consumption management: The other option available to leading sites is to reduce the amount of water required in a process. Assuming that a technology switch to dry processing is not possible (or practical) it is possible to implement other practices to reduce water requirements. One option is to review pulp densities. It is not unusual to find plants running densities that are not optimal. Therefore, there can be capacity to increase density without

creating any compromise with recovery. Depending on the criticality of the need to reduce water use, it is possible to continue to increase densities but with recovery trade-off. If the water is so scarce as to threaten mine shutdown, this option can be explored. For example, a concentrator operating at 10 million tonnes per annum and 40 percent solids can reduce its front end water use by over three megalitres per day by raising pulp density by two percent. There is good evidence that tuning of grinding parameters can also reduce water consumption. For example, coarser grinds and improved particle size classification can allow more recovery of water from tailings but, if sufficient care is not taken, this can result in decreased recoveries. It may also increase the need for maintenance, for example, coarse material collecting in flotation cells. Another option is to review the flocculants employed for settling and compacting tailings. Metallurgists need to exercise caution with flocculants being chosen for their positive effect on settling rate rather than on compaction. Indeed overuse of flocculants, or use of the wrong type of flocculant can retard tailings compaction, which can have longer terms negative consequences for operational water management. Poor consolidation can also have a longer range impact on water management of tailings storage facilities post closure.

Tailings can also be pressed, filtered or converted into pastes, which means less water is entrained and therefore does not need to be recovered from a tailings dam. This may increase the energy required for processing which may be undesirable. However, it may also result in significant cost savings by increasing the functional life of tailings storage facilities. Comprehensive business cases are required to determine the various costs and benefits. However, again, in situations where water scarcity threatens production, thickening options may be attractive.

8.3.5 Product separation—leaching

An increasingly common method of product separation is leaching. Heap leaching, in particular, requires the management of large volumes of water (generally as acidic solutions or containing cyanide). Leaching solutions are added to the top of heaps so there is significant potential for evaporation. Leading practice operations minimise this by ensuring that irrigation rates are well matched to heap infiltration rates so that ponding on the surface does not occur (minimising free water surface for evaporation). Drip irrigation is another option which has the added advantage of reducing problems associated with preferential flow through heaps. Pregnant solution is also stored in and reticulated through ponds which must be lined to avoid losses and may be covered to reduce evaporation (see Section 10.4). Heap leaching pads must be designed to avoid any loss of leaching solution to the surrounding environment. At closure (once leaching is completed) heaps must be decommissioned so that infiltration of rainfall does not create the possibility of movement of residual leaching solution. Maintenance of the leach pad and drainage infrastructure is required to ensure long term stability and safety of the heaps. Solution from which the leached metals have been recovered should be reused as far as possible and any residual liquids contained or disposed of according to site licence requirements.

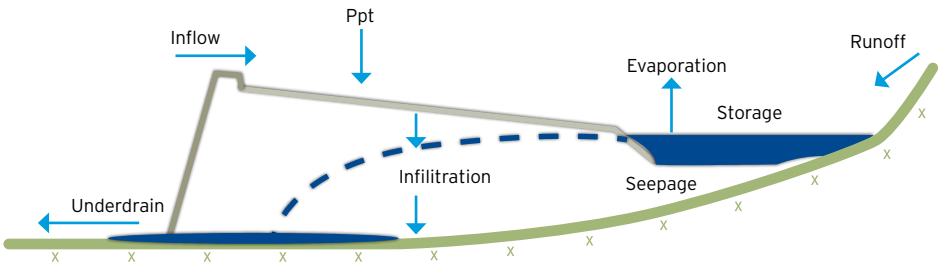
8.3.6 Tailings Storage Facilities

Water balance: On most sites, Tailings Storage Facilities perform the dual roles of tailings storage and water recovery systems, and on some sites they store both tailings and tailings water, particularly where the tailings water is unsuitable for reuse in the processing plant and is required to be evaporated from the facility. Alternatively, excess unusable tailings water may be removed to separate evaporation ponds.

A significant proportion of the water in circulation within a mining operation is associated with the TSF and large water outputs (entrainment, evaporation and seepage) occur in the course of tailings storage. In a dry climate, the volume of water delivered annually to the TSF with the tailings is equivalent to many times the annual rainfall. Up to half this might be lost to evaporation and seepage, with the evaporation increasing the concentration of contaminants and the seepage potentially impacting the environment. Seepage may go directly to the TSF foundation and/or emerge from low points along the toe of the containment walls.

A clear understanding of the water account for the TSF is the key to leading water management of the facility. Figure 10 illustrates the main components of the TSF water balance. Evaporation rates will vary, with the highest rate from the pond, followed by that from recently deposited wet tailings, then dry tailings. A degree of seepage or leakage occurs from the base of all tailings dams and leading practice operations engineer liners and underdrains to, where possible, manage such seepage to avoid any significant impact on local groundwater quality.

Figure 10. Main hydrological components of the TSF water balance.



High density thickened tailings discharge technology: Geotechnical assessments indicate that there are significant advantages with high-density, thickened discharge in terms of seepage reduction, water savings, reduced wall construction costs and operational convenience. Large scale trials at Osborne mine in Queensland, Australia, show that seepage rates reduce to about one percent of the volume of water contained in the slurry and overall water savings of 40 percent are feasible (Mc Phail & Brent 2007). The high-density, thickened tailings discharge design has clear advantages with respect to facility decommissioning as the cone geometry and greatly reduced decant pond size allows for progressive rehabilitation as deposition advances.

Rehabilitation: Conventional tailings facilities may take several years to dry out enough to allow plant access for rehabilitation purposes, particularly at the slimes end of the beach and where the tailings spend considerable time under water. Without the application of leading practice to fine-grained tailings management it is possible that they will remain wet for many years creating long term – or even permanent – legacies which may impact later mining and/or post-closure activities. For example, safety may be compromised if it is never likely to traffic such tailings. Even for well managed facilities, during the drying phase, rainfall rewets the desiccated tailings, exacerbating the release of oxidation products (in the case of sulphidic tailings) and causing renewed seepage thereby hindering rehabilitation. Seepage rates reduce exponentially with time as the tailings drain, but this may continue for many decades after decommissioning of the facility. However, the quality of this seepage water may progressively worsen if the surface layers of the tailings substantially oxidise before the facility is covered, and may require intervention by active treatment. This is an area where the importance of interaction between final landform and water dynamics is highlighted. Good planning which integrates landform and material properties can avoid long-term legacies.

Commonly, TSF closure designs therefore focus on surface drainage management. Retention of the decant pond as a wetland may be acceptable, depending on the nature of the tailings, the final catchment area, and the likelihood of ongoing seepage. An alternative involves paddocking off the top surface, effectively reducing the depth of water stored at any single location and reducing hydraulic gradients. The construction of a store/release cover is widely advocated in dry climates, particularly where the tailings have the potential to contaminate seepage water. A spillway and sediment collection pond are often required to reduce ongoing ponding of water on top of the facility thereby limiting ongoing seepage,. Leading practice closure design is therefore a hybrid of several drainage/water management systems.

Effective management of the TSF is discussed in detail in Leading Practice Sustainable Development Program's *Tailings Management* (www.ret.gov.au/sdmining) handbook. What is important from a water management perspective is the need to maximise water recovery and minimise worked water release to the environment during mine life and after closure. During mine life, this can be achieved by means of correctly engineered under-drains and decant systems. Argyle Diamond Mine in the Kimberley Region of Western Australia, for example, obtains more than 40 percent of its process water from tailings facility water recovery (Argyle 2005). Post closure, the focus must be on leading rehabilitation practice.

8.4 Water recycling/treatment

Water recycling is defined as reusing water following treatment to ensure that it is fit-for-purpose (which may include output release). Water treatment covers a wide range of technologies and operational techniques, and includes both passive and active approaches.

Passive treatment systems generally have lower capital and maintenance costs than active treatment systems. These systems have the potential for long-term success, but there are ongoing costs associated with monitoring and maintenance such as periodic replacement of

limestone or compost, flushing of the system and/or sludge removal. Active treatment is relatively higher in capital and maintenance costs and a more intensive level of monitoring. The advantage of active treatment is a high level of predictability about performance during the operational life of the mine, and an ability to cope with wider variations in both flow and composition Passive systems are likely to be more attractive than active, chemical-based systems for water treatment post closure when they are required to perform a final polishing role.

The optimum treatment approach depends on the water quality requirements for either reuse or discharge. For example, treatment for most mineral processing would not require potable grade water. Leading practice involves matching the appropriate water quality with specific water tasks. A combination of passive and active treatment components may be used to deal with difficult or complex water quality issues. Water quality issues can be categorised into six key contaminant groups: (1) inorganic, (2) organic, (3) suspended solids, (4) biological, (5) nutrients and (6) gases/odour. Water treatment approaches or technologies to deal with common contaminants within each of these categories is included in Appendix 1.

CASE STUDY: Illawarra Coal's water filtration plant is saving water

Since its commissioning in late 2006, Illawarra Coal's $6 million water filtration plant at its Appin West mine (formerly Douglas) is saving the company – and the state – a significant amount of water.

The plant, officially opened in December 2006 by the Hon Ian McDonald MP, Minister for Primary Industries, Mineral Resources and Energy has already returned more than 136 megalitres of treated mine water underground, replacing fresh water which would have otherwise been purchased from Sydney Water.

The first of its kind in the Illawarra and Wollondilly regions, the plant has the capacity to treat for reuse more than two megalitres of mine water each day, equivalent to two Olympic-sized swimming pools. The success of the plant to date is helping the company to realise its goals to improve the water quality discharged into local waterways and to reduce the volume of purchased water the mine uses. Treated water has been used underground in longwall mining equipment, drill rigs and continuous miners, namely for equipment cooling, dust suppression and hydraulic oil emulsion make-up.

Illawarra Coal's water filtration plant. Image Source: Illawarra Coal

A joint project with Worth Recycling, it was intended that the plant would increase Illawarra Coal's recycled water rate and decrease the company's uptake of fresh water from Sydney's water supply.

This has been achieved through the installation of the plant, incorporating integrated mine water pumping systems, treatment systems and freshwater delivery systems. The major process steps are:

- gravity feed from boreholes within the old goaf areas to an underground sump;
- pumping from underground pump stations to surface mine dams;
- multimedia filters - reducing the concentration of suspended solids;
- granular activated carbon filters - reducing the concentration of total organic carbon and microbiological activity;
- microfiltration units—reducing colloidal material;
- water softener—reducing hardness;
- four-stage reverse osmosis system; and,
- fresh water underground and surface tanks and pumping system to supply operations.

The water filtration plant supports Illawarra Coal's multi-pronged approach to saving water, which includes joining Sydney Water's Every Drop Counts Business Program, and the development of water savings action plans for all of its operational sites.

8.5 Site water stores

8.5.1 Runoff management

Discussion in this section is limited to management of water that is directed to stores as part of the operational water inventory. Runoff diversion is dealt with in section 9.6. In most Australian operating conditions runoff is sporadic and often in large quantities over short periods of time, therefore, operations need to be designed and managed to reduce impacts associated with fast flows. This requires striking a balance in site storage capacity—storing sufficient water to provide for drier periods without enhancing the probability of unregulated discharge. The threat of unregulated discharge is a particular concern if the site water inventory carries a contaminant load which is unacceptably high.

The first principal of runoff management is to ensure water is kept clean wherever possible. This provides flexibility. Clean water can be used directly in appropriate tasks. or it can be blended with worked water to provide water fit for a range of purposes. This increases the utility of worked water stores and thereby boosts site reuse. Leading practice management of runoff is based on understanding and managing the main runoff pathways which allows water to be directed (to appropriate stores or off site) and indicates where control measures are best placed to treat any water quality issues that may require attention.

In cases where runoff is not clean, there are a number of leading practices that can be used on flow paths to improve water quality. Technical information is available for management of sediment by controlling: (1) sources through vegetation management and (2) transport by using well-located and constructed control structures. Runoff may also contain unacceptable levels of salt. In these circumstances, evaporation facilities may be necessary if active water treatment such as ion exchange or reverse osmosis is not viable. Some passive treatment systems, such as wetlands with under-drain salt trapping and storage, are also available for salt but these are less widely implemented than those for managing sediment. Low pH runoff may require treatment, such as lime dosing or reticulation through a passive treatment system, before it is suitable for reuse or release. Leading practice management of pathways would include minimising accumulation of flows of water through areas where contamination is like to be greatest; that is, waste rock dumps or haul roads.

8.5.2 Water storage facilities

The fundamental principles for leading practice management of stores are to control losses, to ensure water is of the required quality to meet fit-for-purpose requirements of the site tasks, and to ensure control structures (wall, spillways, sumps and entry channels) are well maintained.

Evaporation and seepage are discussed in sections 10.4 and 10.8.

Ensuring water meets quality specifications may mean maintaining drainage ways, rehabilitation and managing vegetation on runoff catchments, and blending various stores at appropriate times. In some water storages (for example those containing nitrate-rich seepage originating from blast residues in waste rock), it may be necessary to manage nutrient inputs to control algal growth. For example, appearance of toxic blue-green algae can render a store permanently unusable for tasks where there is direct contact between workers and water. Leading sites monitor the physical condition of stores for stratification and turnover events as these may cause rapid and significant changes to water quality (salinity, pH, temperature and oxygen status), which may affect critical site tasks (mineral recovery, or create health and safety risks) which are otherwise difficult to mitigate.

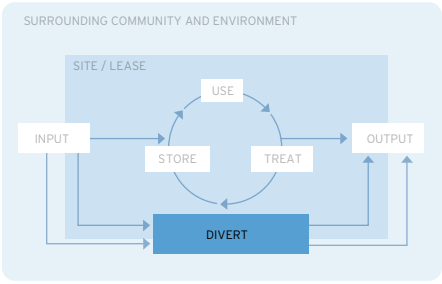
In a carbon-constrained future, design and placement that consider water transport energy costs are becoming increasingly important. Leading sites employ clever use of gravity and locate tasks, such as minerals processing facilities and stores in close proximity to site. Avoiding multiple transfers of water between storages by implementing good operational procedures can save significant energy.

9.0 DIVERT

KEY MESSAGES

- Formal accounting of diverted water allows separation of water involved in the technical aspects of mining from water that is relocated but not impacted in terms of losses or changes in quality.
- Diversion can occur by reinjecting or re-infiltrating groundwater, changing the course of rivers and by redirecting clean surface runoff.
- Leading practice water diversion manages not only the quality of diverted water but also the other values of the water, such as organism habitat and passage and human and operational safety for all stakeholders.

Divert: The tasks and infrastructure associated with diverting water safely around the lease or through the lease while avoiding contact with the operational tasks, infrastructure and stores. Water may be temporarily stored in specific facilities but not in stores used for operational tasks in the use-treat-store loop. There should be minimal losses and water quality should either be improved or not altered. Diversion occurs through pipelines and natural and constructed channels.



Diverted water has three main sources: (1) dewatering of aquifers and underground mines, (2) onsite collection of clean runoff and (3) off-site runoff and flows in watercourses (rivers, creeks, gullies).

The main tasks associated with diversion are pumping and maintenance of infrastructure and channels. Diversion can have significant capital costs, particularly when diversion of watercourses is required. Similarly, design, implementation and maintenance of runoff management can be expensive.

Leading practice operations monitor diverted water quantity, quality and conveyance structures as part of their water accounting and water balancing procedures.

9.1 Key risks

Diversion design not acceptable for approvals:

- Project may be delayed, perhaps indefinitely.

Construction and/or maintenance costs higher than planned:

- Diversion construction involving large earthworks may need to occur well before operation to allow a vegetative cover to establish. Erodible soils or other unfavourable geotechnical conditions along the diversion alignment may require specialised and costly treatment.
- A poorly-designed diversion may require costly ongoing maintenance.

Source not delivering quantity as per diversion infrastructure design:

- Too much water delivered may compromise infrastructure possibly resulting in site flooding with threats to safety, production and environmental licence conditions. Corporate targets for water withdrawals from the environment may be compromised if water is redirected into operational stores to avoid unregulated release.
- Too little water may threaten the capability of the operation to meet output expectations, such as environmental flows.

Source not delivering quality as per diversion infrastructure design:

- There is potential for maintenance problems to occur if water constituents are corrosive.
- There is a potential inability to release water as per licence conditions without undergoing costly treatment. Redirection to operational stores may compromise corporate targets for withdrawal from the environment.
- Ecosystems in stream diversion may be compromised.

Diversion infrastructure operating out of specification:

- Unable to cope with water quantity. The consequence is the same as too much water being delivered to infrastructure working within specification (see above).
- Unacceptable change to water quality caused by the diversion infrastructure.

Post-closure legacies:

- Community or environmental requirements that have become dependant on water sourced from diversion without an agreed closure strategy.
- Water course diversion may need different functional specifications when there is not a mine site management team available to manage their function, such as flood mitigation.
- Water course diversion that are to revert to prior courses need appropriate planning.

9.2 Leading practice control of risks

Leading practice for controlling these risks requires that:

- construction of water course diversions is undertaken only if unavoidable;
- water course diversions are well designed and maintained;
- water sourced from dewatering is properly accounted for and transported for release without undue losses or impacts to the environment on or off site;
- runoff diversion is designed and managed to ensure water is of equal quality to that from the surrounding undisturbed land; and,
- creek/river diversions should be constructed as early as possible to allow the system to stabilise before it is challenged by climate conditions and mining. This will support safer mining and better environmental outcomes. It is recognised that management often prefers to undertake capital expenditure later rather than sooner, however, the ultimate costs of doing so may exceed the savings sought.

The following sections describe leading practice for achieving these controls.

9.3 Watercourse diversions

Leading practice design of watercourse diversions will reduce time and cost associated with the approvals process. The main activities that must be undertaken to plan for and implement a diversion at various stages during the life cycle of an operation are shown in Figure 11.

Leading practice design of watercourse diversions requires that hydraulic, ecological and geomorphological values of the diversion match conditions derived from a reference reach (see Morwell River case study). Such natural channel design (NCD) embodies the principle that an artificial channel designed to mimic a natural one will behave in a manner that provides the best outcomes.

CASE STUDY: Morwell River Diversion

TRUenergy Yallourn supplies 22 percent of Victoria's electricity requirements. Its current coal supplies were expected to be exhausted in 2009, and nearby Maryvale Coalfield presented the best potential future coal supply. However, the Morwell River was located between the mine and this coal reserve. A river diversion was proposed that would lead to economic and environmental outcomes.

Tenders were called in 2000 for the construction of a channel which involved diverting the river away from the power station. The Roche Thiess Linfox (RTL) Joint Venture reviewed the conforming design and developed an alternative and innovative solution that would ultimately save the client millions of dollars and preserve a greater proportion of the natural environment.

The alternative design involved positioning the open channel river on the top of a largely filled embankment constructed on an alignment through old mine workings. The advantages offered by the alternative design were immediately recognised and the company entered into an alliance agreement with RTL for the design and construction of the Morwell River Diversion.

A design team comprising mine planners, geotechnical experts, ecologists, embankment designers and hydraulic engineers was formed. It was agreed the diversion embankment could be constructed in engineered fill from 13 million cubic metres of overburden that needed to be stripped from the mine, significantly reducing the cost of the project. The design required the creation of a 70 metre wide and 3.5 kilometre long diversion channel on top of an embankment that commenced at the Morwell River upstream, and connected with the Latrobe River downstream. The channel design accommodated a 1 in 10 000 year probability flood and was designed to mimic the geomorphic and ecological characteristics of the natural Morwell River. Such features included:

- a river alignment based on the meander in the natural bed of the Morwell River including rock riffles and pools to regulate flows and to provide in-stream habitat;
- native, local provenance vegetation along the low-flow channel to provide erosion protection; and,
- positioning the river on an embankment which minimised the risk of acid water entering the river from the adjoining natural ground.

Aerial photo of northern section of Morwell River Diversion at confluence with Latrobe River showing coal supply conveyor tunnels and road ramp/crossing.

Image Source: TRUenergy.

The layout of the meandering channel meant the river was subject to natural stream behaviour including erosion during floods. A hydraulic model was developed and analysis was undertaken which led to the design including rock lining in high risk areas to minimise erosion.

Critical issues were identified through rigorous risk assessments of the concept design. The most significant issue identified was the capacity of the old overburden dump material to act as a foundation for the very large embankment. A trial embankment, comprising more than 0.5 million cubic metres of fill, was constructed so that the performance of the dumped overburden material could be observed and compared with predicted behaviour. The results verified the technical viability of construction of a 50 metre high embankment.

The Morwell River Diversion project guarantees the life of TRUenergy Yallourn's mine for at least 30 more years by providing short and long-term accessibility to critical coal reserves thereby ensuring continued supply of a major portion of the Victorian and national electricity supply. The following economic, social and environmental outcomes were achieved:

- works on the diversion provided more than 150 construction jobs over the period 2001 to 2005 inclusive.
- without the diversion, the cost of electricity generation would have significantly increased;
- under the Native Title Agreement established, a number of local Aboriginal elders were engaged as cultural observers; and,
- the diversion has delivered significant environmental improvements, compared with the original design, including retaining two kilometres of original river flood plain and ephemeral wetlands.

Other improvements included the rehabilitation of borrow areas into wetlands, incorporation of riffles and pools to support aquatic habitat, establishing local provenance vegetation in the low-flow channel and reducing the risk of acid water entering the river.

- The diversion also preserved significant native vegetation, which included hundreds of the nationally significant Strzelecki gums and some state-significant green scentbark (both eucalypts).
- The project also included the enhancement of an existing weir with a purpose-built fish ladder so native fish could traverse the river upstream of the embankment for the first time in about 30 years.

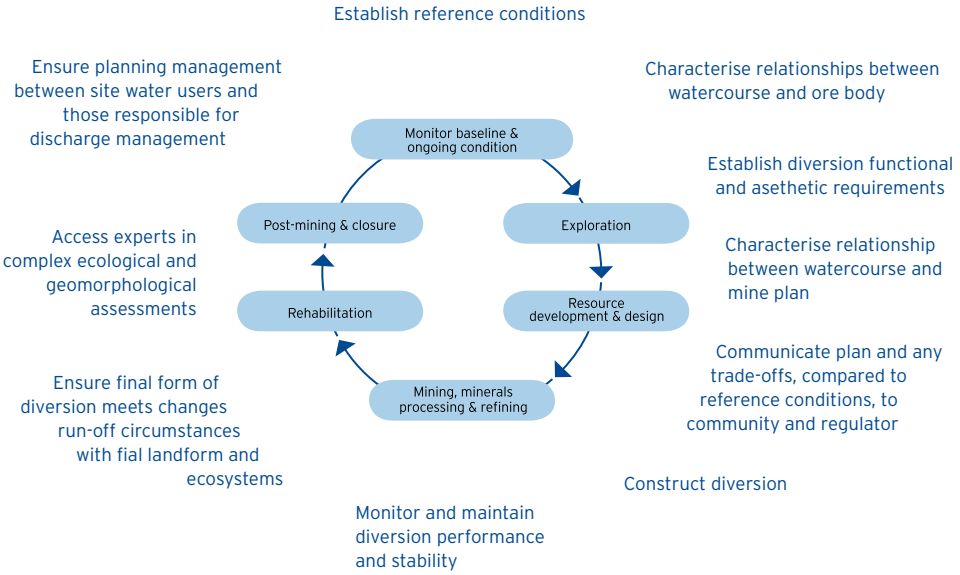
Close up of river meander with native aquatic vegetation development.

Image Source: TRUenergy.

Regular communications were held with, and investigations were performed by Environmental Protection Authority and West Gippsland Catchment Management Authority who were the primary environmental stakeholders of the project. This ensured all activities during the life of the project were monitored and the agreed environmental standards met. Contact TRUenergy Yallourn's Mine Operations Manager for further information (www.truenergy.com.au), or download a fact sheet at www.truenergy.com.au/Production/Yallourn/mining.xhtml

Diversions are similar to drainage structures in that their functional aim is to route flow around and away from the operation in a safe, predictable and efficient manner. Natural watercourses are dynamic (prone to flooding and channel instability), whereas diversions must be stable, contain flows and not affect flood levels to an unacceptable degree. The diversion must also not act as a physical barrier to the migration of aquatic organisms. Operational diversions are, therefore, a trade-off between environmental requirements (values, processes and variability) and certainty in hydraulic and geo-mechanical performance. Economic considerations provide some constraints on the extent to which environmental conditions can be realised compared with theoretical outcomes.

Figure 11. Significant issues in designing and managing watercourse diversion across the life of an operation.



Regulators seek assurance on design and performance from exploration to beyond closure. Leading practice design and comprehensive monitoring provide the best mechanisms for ensuring that a diversion will operate within acceptable limits and will not cause increased rates of erosion, sedimentation or flooding in upstream and/or downstream reaches. A core criterion for a watercourse diversion is that it must be designed to meet the environmental flow requirements (Section 6.3.2) of the watercourse it replaces as well as any contributions from the operation itself.

Diversions are often expensive, particularly where deeper cuts through elevated topography may be required, and must often be constructed before operations start to allow vegetation to establish and minimise erosion risk. Diverted watercourses are sometimes re-instated over modified or mined terrain. Re-instatement over mine backfill provides a range of technical challenges including potential subsidence and interactions between surface and groundwater.

It is not possible to recreate all natural habitat features, for example, a corridor of mature riparian vegetation cannot be created instantly. Leading operations seek opportunities for rehabilitation of other stream sections and incorporation of key ecosystem functions, such as temporarily incorporating artificial habitat structures. Accommodating passage of organisms (aquatic and riparian) must be considered in the design. Sources of information for design of diversions and other structures for fish passage can be found in state guidance documents and Mallen-Cooper (2001) for south-east Australia as well as Rutherfurd et al. (2000) and ACARP (2002). Design must also incorporate interaction with runoff management, entry and exit transition zones, bunds and collector channels and management of erodible soils.

In some cases previous diversions must be reinstated. Similar design considerations as for creation of diversions are required. In some cases, mine activities that have not fully accounted for closure must be overcome by applying leading practice approaches post closure (see Wallsend case study). While this does not have the advantages of early planning for closure, it does demonstrate that acceptable outcomes can be achieved, although likely at considerable additional cost.

CASE STUDY: New Wallsend mine closure project—Maryland Creek re-establishment

Background

On 24 December 2002, mining ceased at New Wallsend mine, located in Newcastle NSW, Australia. The mine is owned by The Newcastle Wallsend Coal Company, a 100 percent subsidiary of Oakbridge Pty Limited. With its purchase of the majority of shares in Oakbridge Pty Limited, Xstrata Coal Pty Limited committed to undertake the rehabilitation, despite not having mined a single tonne of coal.

Closure works—Maryland Creek re-establishment

During the closure process, one of the major technical challenges requiring the application of innovative techniques including the re-establishment of a 500-metre section of Maryland Creek. The creek was originally piped through the site for the purpose of providing for additional coal stockpiling facilities.

Preparations for Maryland Creek re-establishment.

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

Reconstruction on creek line.

The project represented a change to the traditional creek construction/diversion works widely used by the mining industry. The design was developed in consultation with relevant regulatory and relies on the replication of natural processes to ensure long-term stability. To date, it has been found that the riparian vegetation has become self-regenerating and negligible care and maintenance works (erosion repair) has been post closure.

Project significance

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

New Wallsend mine closure before (left) and after (right).

9.4 Dewatering

Leading practice operations design and operate infrastructure for diverting water from dewatering which integrate monitoring and flow controls. This ensures that water quantity and quality requirements are met. Leading operations limit losses from diversion flows by avoiding flows in unlined and/or open channels and maintaining pipeline infrastructure to avoid leaks. Significant energy savings are possible by ensuring pumps are specified appropriately and opportunities to use gravity are sought and implemented.

Leading operations can account accurately for diverted water volumes. Where it is challenging to find beneficial uses for the water, leading operations attempt to incorporate dewatering volumes into operations where this can provide relief from another input source, even if this incurs some additional costs (see Mt Whaleback case study).

9.5 Re-injection

Re-injection is the practice of replacing groundwater into the same or a nearby aquifer. It can be achieved using engineering infrastructure and/or passive re-infiltration via local water courses. In some circumstances it is preferable to releasing water into surface water systems and/or relying on evaporation. Re-injection is considered water diversion when the receiving aquifer is within the lease boundary and as an output when it is outside the lease boundary.

Company policies and government regulations are increasingly requiring such actions to provide better stewardship of water resources. Re-injection requires specific geological and hydrogeological conditions with the added aim of being economically feasible. A re-injection operation should be located:

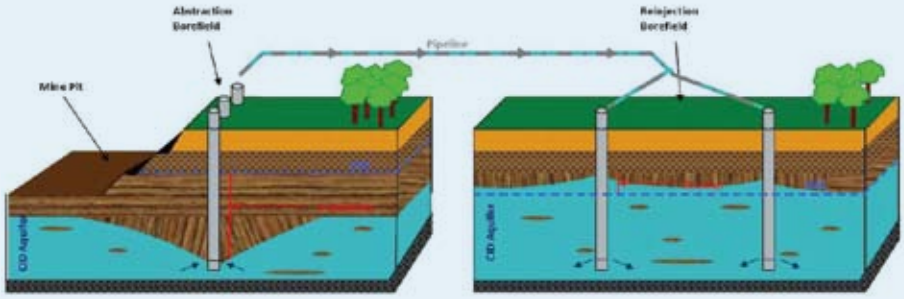
- in geology that has the capacity to receive water at a sufficiently high rate; that is, exhibit at least moderate permeability);
- in an area with a sufficiently deep naturally occurring water table;
- in areas where the injection quality of injected and receiving waters are compatible; and,
- within a reasonable distance of the abstraction source to minimise infrastructure costs, but not so close that dewatering operations are inhibited due to recirculation.

Not all these conditions may be met in all situations where it might be desirable to use re-injection. One example where re-injection is proving feasible is the Yandicoogina iron ore mine in the Pilbara in Western Australia.

CASE STUDY: Yandicoogina aquifer re-injection

Rio Tinto Iron Ore (RTIO) has successfully implemented aquifer re-injection at its Yandicoogina (Yandi) mining operation in the Pilbara region of Western Australia, thereby returning mine dewatering water back into another area of the aquifer.

Mining commenced at Yandi in 1998. A fines iron ore product is produced from the Channel Iron Deposit (CID) ore body. Dewatering is required as the CID ore body is within a significant aquifer system. It is currently standard regional practice to discharge surplus water into existing waterways. However, this has several associated risks including the potential to develop dependent riparian ecosystems on the year-round water supply, in the process losing their adaptation to ephemeral wet season flows. In addition, this discharge may be considered wasteful by other stakeholders, particularly in the dry Pilbara region.



Dewatering Operation

Reinjection Operation

In partnership with consultant MWH, RTIO sought to take an innovative approach to reduce this risk by commissioning the development of an aquifer re-injection system, returning water to the aquifer at an appropriate distance from the mine site.

Aquifer re-injection allows a component of the water extracted to be returned to the environment, limits impact on downstream surface ecosystems, minimises potential discharge impacts on the surrounding environment, and preserves a valuable resource that may be stored and withdrawn in the future.

In order to evaluate the major technical risks of undertaking re-injection at the Yandi site, a trial was undertaken involving the re-injection of 5.3 megalitres per day using a single re-injection bore. The major technical issues identified and managed during this trial were prediction of re-injection rates and the control of clogging in the well screens and aquifer. The former was managed through a thorough understanding of the hydrogeology of the project area, which is the first requirement for a successful re-injection application. Clogging was controlled through the ongoing development and refinement of appropriate

infrastructure, and by selection of pumping and re-injection aquifers with similar water chemistry. Having successfully overcome these issues, a full-scale re-injection program utilising five re-injection bores was commissioned at the Yandi site. This has allowed around 16.5 megalitres per day of excess water to be successfully re-injected since 2006.

Mine dewatering water re-injection at Yandicoogina. Image source: Rio Tinto

The Yandi re-injection program has successfully demonstrated the feasibility of re-injection as a technique for managing dewatering excess and, in the process identified a water management tool that has previously not been utilised for this purpose by the mining sector.

It is important to recognise that although re-injection has been successfully implemented at Yandi, the application of this technology is dependent upon several factors, in particular, the site-specific hydrogeological conditions. Re-injection should not be considered the 'silver bullet' for dealing with all excess water management situations. For those operations where it is appropriate, aquifer re-injection can be a powerful tool for the mining community to utilise in order to preserve the groundwater resource and riparian ecosystem integrity.

The Yandi re-injection project was recognised as leading practice winning the 'Management of Water Resources—Commercial Project' category at the 2007 Western Australian Water Awards.

9.6 Runoff

Some companies have targets to reduce withdrawal of water from the environment. Diverting clean runoff ensures that it does not become part of the site operational worked water inventory. This avoids losses of raw water not needed for production and does not make targets unnecessarily difficult. An operation may also prefer to divert runoff than have it increase the stock of worked water, potentially increasing the risk of unmanaged and/or unregulated releases.

Runoff can only be diverted if its quality meets that from the surrounding landscape that has not been impacted by the operation or in cases where specific licence conditions have been granted. In some cases, operations are required to divert runoff under their licence conditions. Runoff for diversion must, therefore, be kept clean and separated from worked water stores. Runoff water that is used to dilute worked water for release should be considered as part of the site operational water stock and not as diversion water (see Chapter 10).

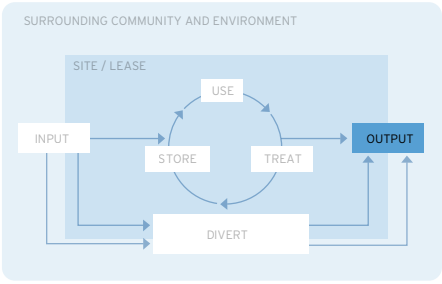
Leading management of runoff is based on understanding and managing the pathways. The first preference for ensuring clean runoff is to prepare slopes and drains so that the water is not contaminated. If this is not possible, then appropriate treatment must be undertaken (Appendix 1). Technical information is available for management of sediment by controlling sources, through vegetation management, and transport, using well located and constructed control structures.

10.0 OUTPUT

KEY MESSAGES

- The way mines manage water output to the receiving environment (or release) may impact company reputation. Leading practice sites may, therefore, be consistently beyond compliance in the way water release/output is managed.
- Leading management of outputs can reduce water inputs thereby increasing security, decreasing operational costs and assisting to meet corporate efficiency targets.
- Effective long-term, post-closure, control of mine water outputs is an indicator of sustainable mining practices.

Output: The tasks and infrastructure associated with managing water output at the interface between the operation and the surrounding environment. The boundary of this interface includes the lease (via pipelines, channels and rivers), underlying aquifers (via bores and dewatering) and the atmosphere (via evaporation). There are two main functions for output tasks:



1. Release of water from site operations (output from use-treat-store—Chapter 8).
2. Sink for water diverted around or through the operation (Chapter 9).

The main tasks associated with outputs are pumping, dust suppression and loading/transport of product. The main design and construction activities are channels, bores and receiving infrastructure (weirs and release points). Output processes and pathways are summarised in Table 8 (see MCA 1997 for further discussion).

Table 8. Output processes and pathways

OUTPUT PROCESS	PATHWAY/SOURCE
Evaporation	Evaporation facilities, stores, channels, co-disposal and tailings facilities, roads (dust suppression), ventilation
Seepage	Stores, channels, co-disposal and tailings facilities, underground losses
Leaks	Pumps and pipes
(Re)-injection	Bore to aquifer, dewatering
Release/discharge	Stores, dewatering, runoff
Entrainment	Product, tailings
Transfer to third party	Pipe, channel, dewatering

10.1 Key risks

Non-compliant release: Release of water that does not comply with licence conditions for quality or quantity results in fines and loss of reputation. It may also be expensive to remediate the receiving environment. Exposure of humans to non-compliant released waters may result in legal action and damage to reputation.

Insufficient output: If dewatering is not kept to schedule, production downtime will occur costing money in lost product output. In some systems it is necessary to maintain output, for example, evaporation facilities, to ensure the operation's water balance meets design requirements.

Excessive output: Excessive losses can contribute to an operation running out of water which may compromise production.

Uncertainty of output: Inadequate monitoring can expose an operation to the consequences of not meeting licence conditions even if they are likely to have been met. With certainty, other water users may be more inclined to enter into supply/use agreements than if supply is uncertain, for example, water co-produced with coal seam gas.

Oversupply from diversion infrastructure: If too much water is supplied from diversion tasks the output infrastructure may not cope causing onsite flooding which may delay production or create safety hazards.

Under supply from diversion and/or production tasks: If a diversion task (dewatering) does not produce water at expected rates, agreements over output rates (environmental flows) may not be met. Contracts for third party water supply may not be met.

Dust not effectively mitigated: Failure to effectively mitigate dust can result in fatalities from accidents and/or exposure of workforce. An operation may experience unscheduled downtime if community agreements over dust control are not met.

Meeting expectations of other users/competitors: Other users may rely on specific volumes and/or timing of licenced releases. Failure to meet these expectations can result in legal challenges and/or damage community relations which may have implications across the operation.

Meeting community expectations: Surrounding community often have expectations about the quality and/or quantity of water outputs regardless of their reliance on the operation. Post-closure water output from water and non-product storages can present significant very long-term liabilities. Raised awareness of the true value of water places increased importance on community relations with respect to water management.

Corporate targets: Output in water-scarce environments will require input of make-up water to compensate. If this is raw water, corporate targets may be compromised. Evaporation, seepage and leaks are the most likely processes of concern.

10.2 Leading practice control of risks

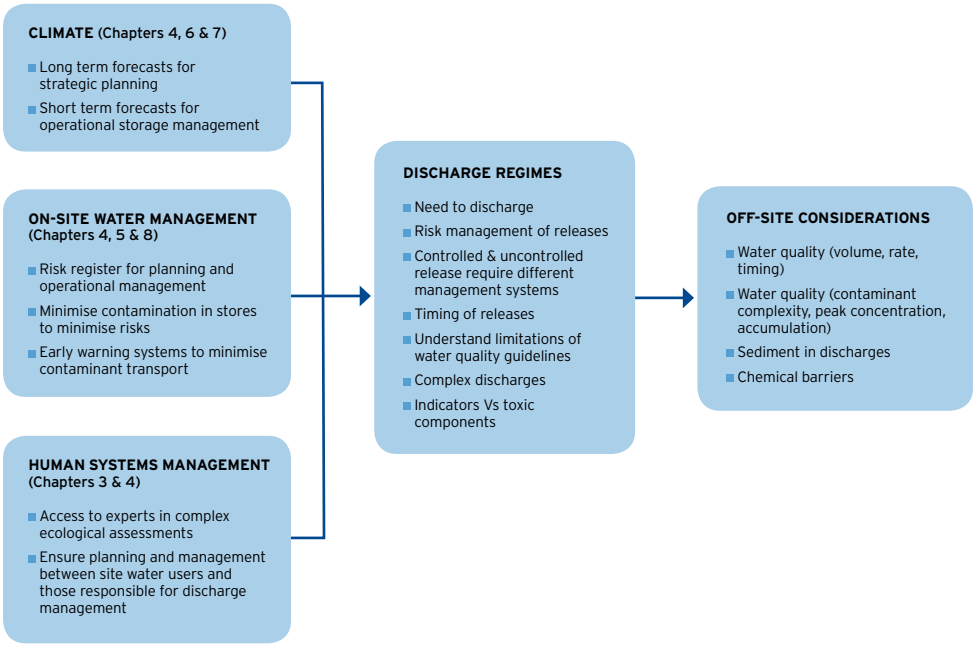
Leading practice for controlling these risks requires that:

- the water output expectations for the operation, over its life cycle, are robustly established, including consideration of climate and hydrological variability;
- all licence, statutory requirements, water release processes and rules for the operation are understood, particularly the impacts of climate variability, and are recorded in the water management plan;
- aquifer injection and aquifer extraction (dewatering) rates are determined with quantified confidence limits. Accuracy will not be possible at the design stage but design should include likely (quantified) variation;
- the site water system is designed to deal effectively with constraints of the receiving environment, reasonable costs of supply and corporate efficiency requirements;
- the capability of the receiving environment to accept the supply is assured and all consequences of doing so have been mitigated. Appropriate use of the Australian Water Quality Guidelines (ANZECC/ARMCANZ 2000) is understood and applied at the operation;
- the responsibilities of the operation for meeting contractual and informal demands of other water users are recorded in the site water management plan and responsibility for performance is transferred to the operators of the water management system;
- mechanisms for proactive response to variability in the above measures are specified in the site water management plan and facilities and staff levels and training are appropriate for their implementation; and,
- closure planning for decommissioning water release infrastructure, and water and non-product stores is essential (see Leading Practice Sustainable Development Program's *Mine Closure* handbook–www.ret.gov.au/sdmining).

10.3 Release/discharge

Why discharge? The key features of managing discharge are shown in Figure 12. Most operations in wet regions release water. In dry areas, which often have large climate variability, it may be possible to store most, but not all, flows. Despite the application of leading practice approaches in water usage, storage and treatment (Chapter 8), there will remain some risk of environmental detriment from altered water quality, or even timing and volumes of clean water resulting from releases (see Section 6.3.2). As a minimum, leading practice operations manage to compliance requirements and apply these standards to design of the water system when seeking approvals. The possibility of uncontrolled releases occurring under maximum probable event conditions should be designed into site structures, such as spillways and failure points for safety requirements in exceptional circumstances. Operating the water management system according to leading practice principles should minimise the need to use these operational contingencies.

Figure 12. An overview of the key factors in water discharge management.



Limiting discharge occurrence: Leading practice limits the volume of water that is contaminated by minimising the opportunities for, and amount by which, contamination can occur. Leading practice operations control the rate and timing of releases as far as practicable.

Optimising release strategies: Controlled releases require sufficient infrastructure to capture and hold water pending release. When well designed, release strategies are responsive to the capacity of the receiving ecosystems to assimilate the released waters. The timing should be chosen to avoid sensitive phases of ecosystem, population or life history processes for key receptors, or to manage the rate of decomposition or alteration of the contaminants within the receiving environments. To minimise mixing zones, the rate of release should be varied in response to the flow rates in the receiving ecosystem. Such proactive management of environmental risks is a better strategy than having releases dictated by production rates and/or rainfall.

ANZECC/ARMCANZ (2000) introduced the concept of direct toxicity assessment (DTA) into the national guideline framework, and this offers considerable advantages for proactive management of discharges, particularly for complex mixtures. DTA measures the toxicity of the whole effluent to a range of organisms and uses this knowledge to predict the potential toxicity to the receiving ecosystems, enabling proactive management of discharge rates and timing. For more information on how to use this approach, see Section 8.3.6 of ANZECC/ ARMCANZ (2000). In addition, it can be far more practical to use DTA as a predictive tool to manage releases into temporary waters than to attempt to monitor the impact of a release post hoc and when management of impacts may be difficult to achieve (see Smith et al. 2004 for further discussion of this).

Proactive and adaptive approaches: Leading practice management of discharges uses the outcomes of sensitive monitoring (see Section 5.1) and understanding of changes to the operation and receiving environments to proactively adjust the management practices during the release. Adaptive environmental risk management strategies, where new information is used to update the risk register and adapt controls, is well-suited to mining operations as they are dynamic processes. Monitoring data and other (external) changes to the circumstances informs the risk assessment which, in turn, informs environmental risk management and leads to a re-assessment of the monitoring program. This cycling back of information into the management of discharges is often missed unless a non-compliance situation occurs, which is not proactive management and not leading practice.

Leading practice uses modelling and characterisation of potential sources of lagged impacts to discharges, such as development of AMD (see Leading Practice Sustainable Development Program's *Managing Acid and Metalliferous Drainage* handbook—www.ret.gov.au/sdmining) to design proactive management systems.

Leading operations have response plans, equipment in place, and staff trained to manage accidental spills such as hydrocarbon or mineral processing reagents.

Contaminants and the receiving environment: It is important to understand the nature of contaminants, the materials being mined and what they are processed with, and the mechanisms by which they may impact on the receiving environment. The key principle is to

understand and screen all potential risks, and prioritise their management accordingly. The risk ranking of contaminants will vary from site to site. Leading practice operations undertake risk assessments when environmental management plans are being designed and incorporate actions to manage risks for all substantial identified risk sources. Leading practice should move towards calibrated model-based and impact process-based quantitative risk assessment rather than categorical methods. Management should extend beyond identifying the key contaminants to understanding the nature of the potential impact processes and key sensitive phases or components in the receiving ecosystems. Without understanding the physical, geochemical and biological processes that can lead to toxicity to key receptors, leading environmental risk management may not be achieved.

Discharges often contain suspended and bed-load particulates and surface-transported materials. These may be directly toxic or create physical environmental effects, such as abrasion, smothering or alteration of habitat structures. Dissolved substances may act as sources or sinks to alter the toxicity of these materials.

Toxicity of some parameters that are commonly monitored may have specified limits in licences but not aquatic ecosystem protection guidelines, and this can lead to confusion. Monitoring of sulfate can be useful, for example, as it is a readily-measured, early warning indicator of acid rock drainage. Sulfate, has low toxicity to aquatic ecosystems, unless concentrations are sufficiently high to cause salinity stress. It is important to separate such indicators from the real stressors in the discharge and manage the stressors, not the indicators.

For complex discharges (those with a variety of contaminants), it may be difficult to predict the toxicity to the receiving ecosystems. How mixtures of contaminants interact and affect toxicity is poorly understood. Measurement of the concentrations of single substances is ineffective. ANZECC/ARMCANZ (2000—Section 8.3.6) introduced, direct toxicity assessment (DTA) for assessment of whole effluent toxicity. This approach is more effective than attempting to fix problems after monitoring has indicated they have occurred because management based on single substance measurements underestimate overall toxicity.

Guideline limitations: The ANZEC/ARMCANZ (2000) guidelines are not designed to be applied to discharges but to the ambient waters that receive discharges (see Section 2.2.1.9 of the guidelines). It is generally true that compliance within the discharge to the default guideline trigger values will result in compliance or better in the receiving ecosystem, and it has become common practice to adopt this approach in dealing with discharge water quality. Nonetheless, this may not be leading practice, depending on site circumstances, and may limit the options for proactive management of environmental risks.

10.4 Evaporation

Evaporation losses can be a major component of a site's water balance. In wet areas enhanced evaporation may be necessary for site to manage excess water effectively. Leading practice ensures that evaporation enhancement is carried-out in an energy-efficient manner. In dry regions it may be desirable to minimise evaporation. A number of techniques are available including covers (physical and chemical), design geometry (small surface area to store volume ratio) and use of underground systems, for example, aquifer or goaf storage and recovery. Recently, Rio Tinto has successfully trialled a new cover approach—floating modules.

CASE STUDY: Minimising evaporation losses from water storage dams

Rio Tinto is currently trialling floating modules to reduce water losses from water storage dams. Water stored at mine operations can be lost through seepage and evaporation. For example, at Parkes (New South Wales, Australia) the average evaporation rate is 4.2 millimetres per day (Australian Bureau of Meteorology), which equals to a loss of 15.3 megalitres of water per year per hectare of storage surface.

Evaporation losses from water storage dams can be reduced by employing structural (wind breaks, reducing the surface area) or cover techniques. Where possible, deep-lined water storages should be constructed with small surface areas, or partitioned cells to allow water to be transferred, thereby minimising the surface area exposed to evaporation.

There are several commercial evaporation reduction covers (floating balls, floating covers, chemical mono-layers and shade structures) that can be employed to minimise water losses from existing dams. The National Centre for Engineering in Agriculture (NCEA), University of Southern Queensland (Green et al (2005)) recently evaluated the cost and performance of some of these techniques. Their report is available on the NCEA web site.

Upon review, Rio Tinto determined that there is a need for a simple commercial modular cover design that could be employed on mine and farm dams without the need for skilled labour, or anchoring systems. The Rio Tinto floating module is a 1.15-metre diameter, circular, domed design that minimises transportation costs, self-packs to maximise water coverage while allowing sunlight penetration and gas exchange. The module also 'adheres' to the water surface without additional anchoring systems. Wind tunnel tests, using scale models, demonstrated that the design was stable in winds of more than 100 kilometre per hour (equivalent to a 100-year return storm event).

Floating modules on water storage dam at Northparkes mine. Image source: Rio Tinto

A 12-month trial at the Northparkes mine (New South Wales) commenced in December 2006 to demonstrate the floating module technique to mining, community, farming and government groups. Two water storage dams were constructed, each with a surface area of about 5,000 square metres. One dam was left uncovered and the other was covered with about 4,800 floating modules. Instrumentation to monitor meteorological data, water quality and evaporation was also installed at the dams.

Previous research work performed by the RMIT University demonstrated that circular floating modules could reduce the yearly evaporation loss by at least 75 percent (Burston 2002). Results from the December 2006 to June 2007 demonstration trial have shown an evaporation reduction of up to 90 percent, saving 7.2 megalitres of water per hectare of dam surface. To date the water quality (dissolved oxygen, pH, conductivity and algal content) has remained the same.

After validating the module's performance and cost, Rio Tinto intends to transfer the intellectual property to a third party who would commercially manufacture and market the floating modules.

This is an example of the use of new technology to tackle an old problem. The concept was developed from prototype though to a manufactured item including mould development. Currently it is being developed to a commercially available product. In 2007, Rio Tinto won the NSW Minerals Council's Environmental Excellence award for this work.

Rio Tinto has a number of sites with water supply issues. Several of these sites store water during winter to manage supply restrictions during summer months. An approach from an academic institution to co-develop new technology was supported by two sites that saw the potential to reduce evaporation losses from their storage dams.

10.5 Dust suppression

Dust suppression is considered as a water output because the majority of water applied to control dust is lost to evaporation. Dust must be controlled on roads, industrial areas, underground, stockpiles and in some mining areas. This includes areas where materials are handled off the mine lease, such as ports, processing facilities and transport load-outs. Dust mitigation is required for safety, production efficiency and to maintain community relations. A large proportion of water used for dust suppression can be lost as evaporation and seepage, leaving salts which can be mobilised by runoff at a later time. Therefore, it may be necessary to plan that dust suppression in certain areas—where runoff contamination is unacceptable and cannot be controlled with appropriate drainage management—using less salty water.

Leading operations have put significant effort in researching methods to suppress dust without excessive water consumption. Strategies include route planning (with sensitivity to ambient environmental conditions, for example, less watering is required in wetter conditions), optimising truck speeds and wetting rates, application of dust suppressants, increased attention to haul road maintenance and developments of efficient spray technologies.

10.6 Entrainment

Entrainment is the process whereby water is trapped in pores or flows or between particles in non-product (tailings, waste rock, coarse rejects) and product materials. Non-product materials are generally stored long-term in purpose-built facilities at the mine sites. These facilities are expensive to design and construct and so there is a strong financial incentive to minimise the amount of space in the facility that is occupied by entrained water. Wet materials may be less stable than those that have been effectively dewatered. Further, any water that is entrained in these materials must be replaced by makeup inputs to the operation. Moisture content control over dewatered product materials is also critical for transport, dust control at ports and meeting product specifications. Therefore, management of water entrained in product is a balance between too wet and too dry. In some cases, product is transported off site as a concentrate slurry with water. Finally, water must be removed from the product before refining or shipping and the water must be disposed of at the facility. In some cases, this water may be returned to the original operation as an input or become the input to another operation. Industrial ecology complexes (regions where industries plan and implement sharing of outputs, such as water excess from one operation becomes input to another to mimic processing of 'wastes' in ecosystems) attempt to capitalise on these opportunities.

10.7 Re-injection

Re-injection (see section 9.5 for more information) can be considered as output when the receiving aquifer is outside the mine lease boundary.

10.8 Seepage

Seepage losses can be controlled by lining stores during construction, with bentonite or plastic for example. In some cases (inpit stores), lateral transport of water into highwall strata may be an output which is difficult to control.

11.0 WATER CONNECTIONS

KEY MESSAGES

- Leading practice water management can cross more than one operation.
- Climate change is affecting the degree of uncertainty on hydrological and general operating conditions at all sites.
- In regions where there are several mines, water users should ensure strategic linkages are made between operations to optimise water resource value and manage cumulative impacts.
- Water management skills are in high demand and in short supply. Leading operations develop and share knowledge and work collaboratively to improve performance.
- Research and development is an essential part of continuous improvement in leading practice water management.

This handbook has illustrated the very wide array of areas in which water is involved in mining and minerals processing/refining. There are a number of issues which do not fall neatly into the management framework for the handbook presented in Figure 1.

Climate change: Climate change is an issue that is now accepted as the responsibility of all. Water is connected with climate change due to alterations to amounts of rainfall, their timing and intensity, and the possible increases in evaporation. In many environments, leading operations are reconsidering the water system design specifications in light of potential changes. Reconsideration includes design specifications for infrastructure such as water storages and TSF to ensure that they will withstand hydrological events that are likely over their operational life and beyond closure. In some cases, it is expected that water availability may decrease. Decreasing water consumption is a sensible leading practice adaptation because even if water remains accessible, it is likely to increase in cost. Leading operations are also recognising that their relations with surrounding communities may need reassessing as these communities undergo changes. For example, current federal policy is supporting landholders to exit agriculture in the appropriate circumstances. This may change community demographics in mining operating environments.

Cumulative impacts: Many mining operations exist in areas where there is a concentration of activity due to mineralisations/coal fields, ports, transport infrastructure and energy sources for refining. In such places, there are likely to be cumulative impacts of multiple operations over time. Cumulative impacts arise as the result of multiple operations and may affect

community, environment, infrastructure and housing availability. Water is subject to cumulative impacts involved in most of these issues. Cumulative impacts need to be addressed through collective planning and action, and this can provide a significant challenge for individual operations. The coal industry's participation in the Hunter River Salinity Trading Scheme is a good example of government legislation supporting collective planning and action. Various Hunter River water users have been allocated salinity credits based on the capacity of the river in various reaches. Salinity credits can be traded or used to release mine water into the river under specific conditions. This system is allowing an organised and environmentally appropriate release of salty mine site waters.

Connecting issues: Water involves use of people, materials and energy. There is emerging a realisation that leading practice must take account of collateral impacts. For example, in an attempt to meet corporate water targets using leading practice approaches, an operation may decide to install a water treatment plant only to realise that this will put the operation behind its energy and greenhouse emissions targets. Increasingly, interconnectivity between issues will need to be assessed quantitatively to ensure that leading operations effectively manage a range of potentially competing objectives.

Connecting operations: There is an increasing trend to connect operations to provide flexibility in water systems. This handbook has provided a framework into which water sharing arrangements can be managed from the point of view of one or other of the operations involved. However, leading practice at a regional level is only just emerging. For example, clusters of industrial activities such as at Gladstone and Kwinana are beginning to demonstrate that a regionally-integrated system of leading practice water management can be developed. This approach has wide applications in other regions where there are many operations, for example, Kalgoorlie, Hunter Valley, Central Queensland and Pilbara.

Skills: Leading practice as described in this handbook requires considerable skills. Not all operations have a team solely responsible for water or even a dedicated water manager. Therefore, it is increasingly important that personnel who do share responsibility for water issues are effectively trained and are supported by corporate schemes to share knowledge. Tertiary institutions have an important role to play in designing and delivering training courses which are relevant and accessible to those working in shifts in remote locations.

New knowledge: Leading practice is dynamic and evolving. Industry-wide leading practice ensures that there are processes in place to develop and deliver new knowledge. Research and development is an effective mechanism for reducing costs and improving productivity, returns, occupational health and safety, and sustainability. Leading practice includes investment in programs of research and development, and their communication and dissemination. This means having testing protocols on site for new technologies that allow for learning,such as providing a testing and development environment that does not risk operational productivity or compliance. A major challenge is to formulate and deliver communication materials on new knowledge to the workforce. Few mining professionals have the opportunity to read copious technical publications.

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GLOSSARY

Diversion task	A diversion task manages raw water to facilitate mining and processing operations. A diversion task does not connect with site stores. It does not transform raw water into worked water. It displaces raw water, with some losses.
Entrainment	The water that is contained in the rock or coal after it is processed. The moisture content after processing is usually greater than before processing.
Evaporation	The process by which water is converted from liquid to vapour and is lost to the atmosphere.
Fit-for-purpose	Water is considered fit for a particular purpose when the constituents in the water are at levels lower than what would be considered as a limit to its use. Often this facilitates the use of water with quality far less than fresh or potable water. Water may be made fit for a particular purpose by various levels of treatment. Ensuring that as much water is fit for purposes as possible allows an operation to maximise its reuse of water.
Groundwater	Water beneath the earth's surface that fills pores between porous media—such as soil, rock, coal, and sand—usually forming aquifers. In some jurisdictions the depth below the soil surface is also used to define groundwater (although different states may use different depths).
Hazard	A hazard is a source of potential harm.
Leading practice	Best available current practice promoting sustainable development.
Licence-to-operate	The permission government gives to the mining industry to mine and produce minerals from specific operations through formal legislative and legal agreements.
Marine water	See sea water.
Non-product solids	Non product solids are all the solid materials that an operation must manage that are not part of the product/commodity stream. They include waste rock and tailings.
Operational task	An operational task uses a combination of raw, worked and treated water (depending on the nature of the task) sourced from a site store. Some of the water is lost. The remainder is transformed into worked water, which can be stored and used again.
Opportunity	The possibility that vulnerability may be exploited to cause benefit to a system, environment, or personnel.

Raw water	Water that has not passed through a site water task, such as rainfall (see Table 4).
Receiving environment	The receiving environment that surrounds and is downstream (or down aquifer) of an operation's lease.
Recycling	See definition in section 8.3.1.
Reuse	See definition in section 8.3.1.
Risk	Risk is the chance that something will happen that impacts on objectives. It is often specified in terms of an event or circumstance and the consequences that may flow from it.
Sea water	Water from oceans, seas and estuaries. Sea water has salinity more than 52 000 ↔S/cm.
Seepage	The process by which water leaks through the base or sides of a water store.
Social licence-to-operate	The social licence to operate is the recognition and acceptance of a company's contribution to the community in which it operates, moving beyond meeting basic legal requirements towards developing and maintaining the constructive stakeholder relationships necessary for business to be sustainable. Overall, it comes from striving for relationships based on honesty and mutual respect.
Store	Stores are the facilities on a site which hold and/or capture water. They are the internal supplies for tasks and must supply all water that is not imported in a given timeframe of demand. Many sites deal with a wide range of water storage facilities from pits where mining has ceased to underground caverns/ goafs, aquifers, surface earth structures and tanks made from a variety of materials (cement, iron, plastic) in a wide range of sizes.
Surface water	All water naturally open to the atmosphere, except oceans and estuaries.
Sustainable development	The meeting of the needs of the present without compromising the ability of future generations to meet their needs.
Task	A task describes the uses to which water is put in an operation. The term 'task' is preferred over 'use; due to the implication of the latter that water somehow disappears and/or is unavailable for other applications after it is 'used'. Further, it is consistent with the concept that water is 'worked' once it has been through a 'task'.
Threat	A threat is the possibility that vulnerability may be exploited to cause harm to a system, environment or personnel.

Water account	see Section 4.4.
Water balance	see box in Section 4.4.4.
Worked water	Water that has passed through a site water task at least once, for example, process water, tailings return (see Table 4). The term is preferred to alternatives such as ‘dirty’, ‘contaminated’ or ‘used’ as each of these carries potential implication that the water is no longer a valuable resource. Rather, worked water may be fit (suitable) for any number of purposes either with or without various levels of treatment.

APPENDIX 1—WATER TREATMENT

Main types of water treatment and their application domains in mining operations.

WATER MANAGEMENT ISSUE	SOURCE	PASSIVE TREATMENT	ACTIVE TREATMENT
TURBIDITY / TSS			
Suspended soil/rock particulates	Earthworks, cleared/ disturbed land surfaces, site facilities such as waste rock piles, stockpiles, haul roads, drilling additives (bentonite, kaolinite, montmorillonite), process chemicals, coal fines	Careful civil engineering (eg. cut-off/diversion drains, road culverts) Maintaining strategic vegetation Progressive rehabilitation and revegetation Silt fences Check dams Straw bale barriers Grassed drainways Settling/evaporation dams Wetlands/ponds	Coagulants/ flocculants - Inorganic (alum, iron salts) - Polymers (polyacrylamide based) Pressure/gravity filtration Thickeners Tailings thickening
NUTRIENTS			
Phosphate (PO_4)	Septic/sewage waste, soil erosion, fertilisers	Wetlands/ponds Septic tank (sewage)	Precipitation (using Ca, Al, Fe salts) Biological removal
Nitrate (NO_3), nitrite (NO_2), TKN	Explosive residues, septic/sewage waste, process water, process chemicals (eg. $Pb(NO_3)_2$, $NaNO_3$)	Wetlands/ponds Septic tank (sewage)	Denitrification under anoxic conditions (biological)
Ammonia (NH_3)	Process water, process chemicals, explosives, landfill leachate	Aerobic wetlands/ponds	Aeration Chemical/biological oxidation
INORGANIC PARAMETERS			
Salinity (SO_4, Cl, NO_3, HCO_3)	AMD, seepage, evaporative concentration, process water, process chemicals (eg. $CuSO_4$, $Pb(NO_3)_2$, $NaNO_3$, hypochlorite, Cl_2)	Water storage covers (retard evaporation) Evaporation basins (enhance evaporation) Aquifer storage and recovery Minimise AMD generation (refer to *Managing Acid and Metalliferous Drainage* handbook)	Membrane processes, e.g. reverse osmosis Electrodialysis Ion exchange Bioreactor systems (metal and sulphide precipitation) Sulfate removal by precipitation/thermal crystallisation processes
Metals (Fe, Mn, Al, Cu, Cd, Pb, Zn, Ni, Cr, As, Sb, Se, Hg, etc.) Acidity	Natural, AMD, seepage, groundwater, drilling additives (eg. $BaSO_4$, Fe_2O_3), process water, process chemicals (eg. HCl, H_2SO_4, HNO_3)	Minimise/treat AMD generation (refer to *Managing Acid and Metalliferous Drainage* handbook) Settling pond Aerobic wetlands/ponds (oxidation/neutralisation) Anaerobic wetlands/ponds (reduction/neutralisation)	Metal hydroxide precipitation (oxidation/ neutralisation) Metal sulphide precipitation (reduction) Ion exchange Membrane separation (reverse osmosis, electrodialysis) Bioreactor systems (metal and sulfide precipitation)

WATER MANAGEMENT ISSUE	SOURCE	PASSIVE TREATMENT	ACTIVE TREATMENT
Alkalinity	Process chemicals (eg. caustic soda, lime, magnesium oxide), cement (eg. shotcrete)	Aerobic wetlands/ponds	Neutralisation Aeration
Low dissolved oxygen (DO)	Groundwater (mine dewatering), coal mines, septic waste, stratification in open water bodies, algae (see below)	Aerobic wetlands/ponds	Aeration Chemical oxidation
Cyanide (and thiocyanate)	Process water, process chemical, seepage, groundwater	Natural degradation (sunlight) Biological degradation	Caros acid/lime Hydrogen peroxide INCO process SART (sulfidisation, acidification, recycling and thickening) Iron-cyanide precipitation Activated carbon polishing Chlorine dioxide Alkaline chlorination Biological treatment
Radioactive components (U, Th)	Result of processing	Aerobic/anaerobic wetlands	Precipitation
ORGANIC CONTAMINANTS			
Biochemical oxygen demand (BOD)	Nutrients (see above) Septic/sewage waste	Wetlands/ponds Septic tank (sewage)	Aeration Chemical/biological oxidation
Chemical oxygen demand (COD)	Nutrients Septic/sewage waste Groundwater (mine dewatering)	Aerobic wetlands/ponds	Aeration Chemical/biological oxidation
Hydrocarbons (diesel, petrol, oils, greases)	Vehicle operations	Hydrocarbon storage: - Safe, fully bunded areas - Constructed and managed to Australian Standards and MSDSs Management of spills: - Absorbents - Perimeter bunding - Interception drains - Wetlands / ponds	Pump and treat In-situ oxidation Air stripping Oil/water separators Composting for spills on soils/rocks ZVI permeable reactive barriers Thermal desorption Microbial treatment
Xanthates Xanthan gum, guar gum, glycol, carboxymethylcellulose, polyanionic cellulose (PAC), starch, polyelectrolytes	Process water, process chemicals, drilling additives	Aerobic wetlands/ponds Oxidation	Aeration Chemical oxidation

WATER MANAGEMENT ISSUE	SOURCE	PASSIVE TREATMENT	ACTIVE TREATMENT
BIOLOGICAL CONTAMINANTS / PATHOGENS			
Algae	Natural, enhanced by nutrient pollution	Wetlands/ponds (nutrient control) Careful civil engineering (drainage control)	See above (active treatment methods for nutrient control)
Bacteria (eg. legionella)	Septic/sewage waste, landfill leachate	Careful selection of drinking water sources	Sterilisation - Ultraviolet light - Chemical treatment (ozone, chlorine) Filtration/micro-filtration
Protozoa (eg. giardia, cryptosporidium)	Natural, septic/sewage waste	As above	As above
Faecal coliforms (eg. E. coli)	Septic/sewage waste	As above	As above
Water-borne disease (eg. malaria, dengue fever)	Stagnant/open water bodies	Minimise area of stagnant / open water bodies Provide health education	Insecticide spraying
GAS EMISSIONS / ODOUR			
Hydrogen sulphide (H_2S) Methane (CH_4) Volatile organic compounds (VOCs) / Volatile fatty acids (VFAs) Carbon dioxide (CO_2)	Groundwater (mine dewatering), septic/ sewage waste, landfill leachate, bacterial decomposition of organic matter within a water body (eg. above/below ground), hydrocarbons (see above)	Aerobic wetlands/ponds	Aeration Chemical oxidation Precipitation
Radon (Rn)	Natural or accelerated release from geologic sources	N/a	Routine monitoring

Handbooks in the Leading Practice Sustainable Development Program for the Mining Industry Series

Completed

- Biodiversity Management – *February 2007*
- Community Engagement and Development – *October 2006*
- Cyanide Management – *May 2008*
- Managing Acid and Metalliferous Drainage – *February 2007*
- Mine Closure and Completion – *October 2006*
- Mine Rehabilitation – *October 2006*
- Risk Assessment and Management – *May 2008*
- Stewardship – *October 2006*
- Tailings Management – *February 2007*
- Water Management – *May 2008*
- Working with Indigenous Communities – *October 2007*

Future Titles

- Hazardous Materials Management
- Monitoring, Auditing and Performance
- Particulate, Noise and Blast Management

These themes do not limit the scope of the program, which will evolve to address leading practice management issues as they arise.

Electronic versions of completed titles are available at www.ret.gov.au/sdmining

For further information on the program or to request hard copies of these Handbooks please email sdmining@ret.gov.au.