Australian Government

WATER STEWARDSHIP

Leading Practice Sustainable Development Program for the Mining Industry

September 2016

INDUSTRY.GOV.AU | DFAT.GOV.AU

WATER STEWARDSHIP

Leading Practice Sustainable Development Program for the Mining Industry

September 2016

Support for the LPSDP was provided by the Australian aid program administered by the Department of Foreign Affairs and Trade due to the reports' value in providing practical guidance and case studies for use and application in developing countries.

Cover image: Maximising water reuse through the Coal Handling and Preparation Plant at Anglo American's Moranbah North mine in Queensland. Water is collected and stored in several dams for reuse. © Anglo American.

September 2016.

Contents

CASE STUDIES:

ACKNOWLEDGEMENTS

The Leading Practice Sustainable Development Program is managed by a steering committee chaired by the Australian Government Department of Industry, Innovation and Science. Each theme in the program was developed by working groups of government, industry, research, academic and community representatives. The leading practice handbooks could not have been completed without the cooperation and active participation of all members of the working groups and their employers who agreed to make their time and expertise available to the program. Particular thanks go to the following people and organisations who contributed their expertise to the *Water stewardship* handbook:

Ms Kristina Ringwood
Chair and Lead Author
Environment and Water Consultant

Mr Michael Butcher
Environmental Engineer
Newcrest Cadia Mine

Dr Claire Cote
Environment Manager
Anglo American

Mr Blair Douglas
Water Practice Lead
BHP Billiton Iron Ore

Mr Mike Harold
Principal Advisor Water Policy
Rio Tinto Iron Ore

Professor Neil McIntyre
Director of the Centre for Water in the Mining Industry
Sustainable Minerals Institute

The Water Stewardship Working Group would also like to acknowledge the kind contribution of case studies and additional comments from Dr Tamie Weaver (ERM); Dr Howard Smith (HDS Technical Management and Consulting); Meaghan Wright (OZ Minerals); Rynhard Kok (Newmont); Nathan Johnston and Nicole Dendle (Fitzroy River Partnership); David Frith (NSW Minerals Council); Chris McCombe (Minerals Council of Australia); Geoff Blackford (Premier Coal); Sue Henderson (Henderson Geotech); Ian Callow (Centre for Water in the Mining Industry); and Paul Ricketts, Chris Oppenheim and Jordin Barclay (Fortescue Metals Group).

The Water Stewardship Working Group would also like to acknowledge the contribution made by the authors of the 2008 version of this handbook, of which the principal author of which, Professor Chris Moran, is now the Director of the Sustainable Minerals Institute at the University of Queensland.

FOREWORD

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

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

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

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

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

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

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

Senator the Hon Matt Canavan

Minister for Resources and Northern Australia

The Hon Julie Bishop MP

Minister for Foreign Affairs

INTRODUCTION

Governments, communities and industries are experiencing unprecedented concern about water resources as a result of increasing demand from fast-growing populations, unsustainable water practices and climate variation. Stakeholders have growing expectations about how large water users, such as the mining industry, manage water.

The Pacific Institute (n.d.) defines corporate water stewardship as:

> An approach that allows companies to identify and manage water-related business risks, understand and mitigate their adverse impacts on ecosystems and communities, and contribute to and help enable more sustainable management of shared freshwater resources. Stewardship is rooted in the concept that robust and effective public water governance is critical to the long-term business viability of water-intensive industries and that companies can play a role in helping to achieve this end. As such, stewardship approaches result in companies improving water efficiency within their own operations, encouraging good practice throughout their supply chain, and collaborating with others to advance sustainable water management.

The aim of this updated handbook is to share with operational and corporate personnel practical approaches to improving mine water management and reducing water risk by practising water stewardship. The handbook provides guidance on taking a risk-based approach and developing practical, fit-for-purpose solutions to mitigating risks. Water stewardship is a broad topic that covers operational, strategic and organisational aspects. The complexities associated with managing water can exist above the level of a single operation and may be important across a region, the whole of a company or even the industry in the national or global context.

Since the handbook was last revised in 2008, the mining industry has continued to experience challenges associated with water management, such as scarce water supplies, managing the impacts of flooding and dewatering, and water quality concerns. In some cases, these issues have resulted in financial exposure for companies arising from delayed project approvals, regulatory uncertainty, constraints on production, property damage and reputational impacts.

Stakeholders expect mining companies to have a better understanding of the interaction of mining with catchment-wide water resource management and to adopt measures that have neutral or positive cumulative impacts. Access to water is recognised as a basic human right and a fundamental ecosystem requirement. At the state and national levels, recent regulatory changes now require comprehensive assessment of the impact of new mines on water resources. At the global level, shareholder representatives, non-government organisations and financial institutions are encouraging the development of standards for businesses to recognise that water is a shared resource with high social, cultural, environmental and economic value. Those standards include greater disclosure and transparency by businesses about water risks, including operational, catchment and supply-chain risks.

In many cases, the Australian mining industry has responded positively to these challenges. The industry has focused on operational water management and has made recent commitments to key national and international water initiatives that are designed to promote improved performance in water management. However, further work is needed to support continued implementation of best practice water stewardship, including strategy, management and operations.

Leading practice is constantly evolving as operations improve the way they do things as a result of new ideas, new technologies or increased effort. It will always be dynamic and ever more challenging. Therefore, leading practice is truly continuous improvement, rather than an auditable end point.

The integrating theme used to bring this handbook together is risk management. Risk management provides a consistent approach based on the likelihood of an impact occurring and the resulting consequence for the site based on financial, social and environmental aspects. Such an approach allows a site to identify and prioritise water risks for subsequent mitigation based on the individual company's tolerance of risk. Risk management is not described in detail in this handbook, as it is dealt with in *Risk management,* another handbook in this series (DIIS 2016).

This handbook has been structured to reflect the broad range of water management risks shown in Figure 1 and described below. Avoidance or mitigation of these risks is central to leading practice water stewardship.

Part I: Drivers for water risk. This section identifies the types of drivers that can create operational and strategic risks in water management and the need for a strong business case to describe why the mining company should spend time and money on an improved water stewardship program (Section 1).

Part II: Water governance. Water governance refers to the range of political, social, economic and administrative systems that are in place to manage water resources. This section provides an overview of the Australian regulatory framework for water that companies are required to comply with to protect the environment and water resources (Section 2). Water governance also applies to the standards, systems and accountabilities for water in the individual company, as well as the processes needed to engage and coordinate resources and responsibilities among multiple stakeholders in a catchment. The leading water initiatives being promoted by the mining industry, the financial sector and various non-government organisations are also covered (Section 3).

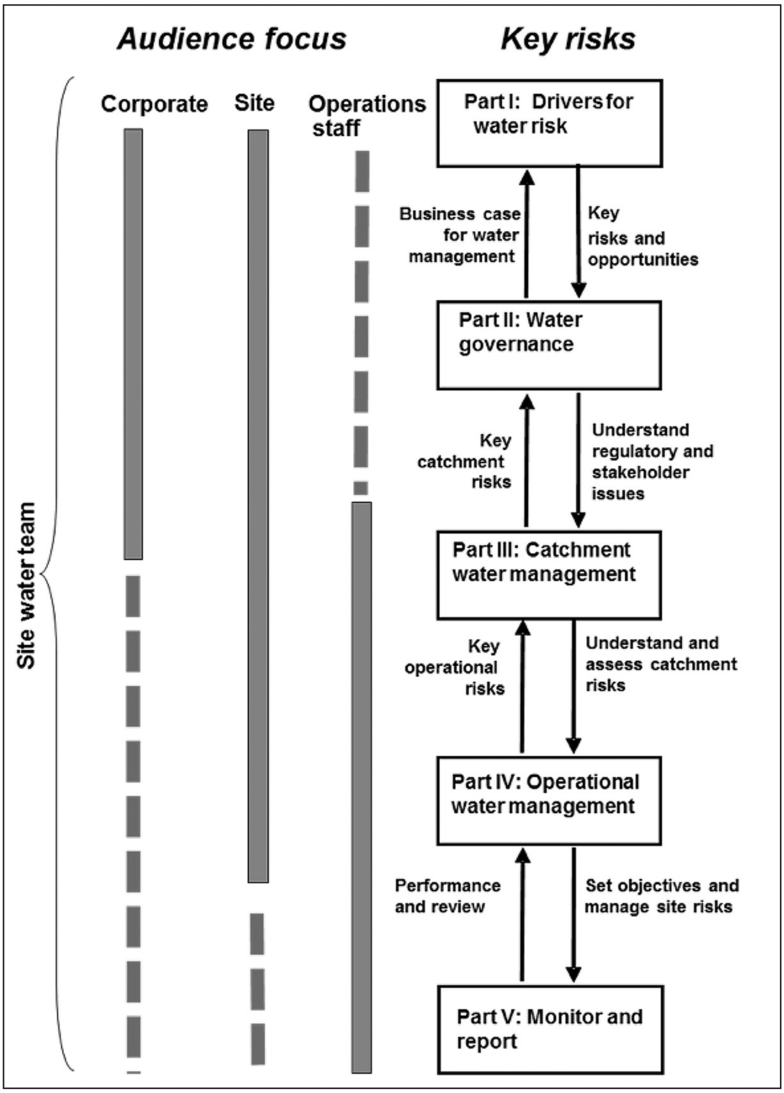
Part III: Catchment water management. Water stewardship today increasingly involves the consideration of water-related issues beyond operational boundaries and requires proactive engagement with relevant stakeholders. Part III provides an overview of water as a shared and finite resource with high social, cultural, environmental and economic value. Operations need to understand their own water use, the catchment context, catchment water planning and shared risk with other stakeholders in the region (sections 4 and 5). Section 6 gives guidance on how to understand catchment-related risks, such as regional surface and groundwater resources, hydrological change, climate variation and change, and baseline environmental flows.

Part IV: Operational water management. Part IV outlines the elements of leading practice operational water management. Section 7 emphasises the importance of taking a risk-based and adaptive approach to water management, as well as building in appropriate timeframes to manage water risk. Clear objectives need to be set to align with the level of risk, using such tools as the site water strategy and the water management plan. From understanding the interaction of the mine in the surrounding catchment (Section 8), to the water management considerations required in developing and operating the mine (Section 9), to optimising the mine water system (Section 10), there will be varying degrees of complexity, depending on the nature of the operation.

Part V: Monitor and report. The development of water accounts that identify the water inputs and outputs for the site is a key step in understanding water flows and opportunities for improvements in water stewardship (Section 11). Part V also provides guidance on processes for monitoring, auditing and reporting in accordance with leading practice standards (Section 12).

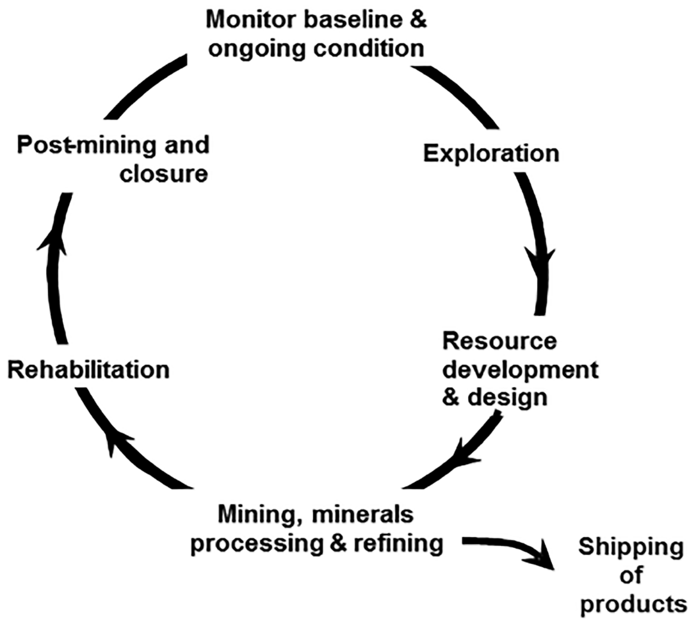
A series of case studies throughout the handbook show how individual companies are responding to water stewardship challenges.

Figure 1: The key features and focus groups of leading practice water stewardship



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

Figure 2: The main operational phases in a mining operation life cycle



Water stewardship involves many disciplines, including engineering, biology, ecology, hydrogeology, hydrology, the social sciences, and health and safety. This handbook gives an overview aimed at all those disciplines. Many of the details of leading practice water stewardship specific to those disciplines or to the stages in the mine life cycle are covered more fully in the other handbooks in this series, as summarised in Table 1.

Table 1: Leading Practice Sustainable Development Program handbooks

HANDBOOK	CONTRIBUTION TO WATER STEWARDSHIP
EVALUATING PERFORMANCE: MONITORING AND AUDITING	Design of water monitoring programs in rock dumps, mine pits, tailings storage facilities, groundwater, surface water ecosystems and discharges
TAILINGS MANAGEMENT	Design and operations of tailings storage facilities for water management and recovery in operational and post-closure phases
COMMUNITY ENGAGEMENT AND DEVELOPMENT	General guidance on community engagement relevant to water consultation, monitoring and social risks
MINE REHABILITATION	Role of hydrological properties of soil in rehabilitation design, water management objectives, and related design and operational guidance
RISK MANAGEMENT	Risk definition and risk management principles; water business risk, including case studies; risk evaluation approaches
BIODIVERSITY MANAGEMENT	Water and riparian management and monitoring related to ecosystems protection and restoration
WORKING WITH INDIGENOUS COMMUNITIES	Understanding indigenous water rights and culture; leading practice for negotiation and co-management of water
PREVENTING ACID AND METALLIFEROUS DRAINAGE	Detailed guidelines on sources and management of risks from acid and metalliferous drainage and other leachates
HAZARDOUS MATERIALS MANAGEMENT	Water as a solvent and transport medium for specific hazardous chemicals; risks to water environment and supplies from hazardous chemicals
ENERGY MANAGEMENT IN MINING	Examples of achieving energy efficiency through water management
COMMUNITY HEALTH AND SAFETY	Communicating and managing risks to local and wider communities
WATER STEWARDSHIP	Drivers, principles and case studies of water management from perspectives of resource stewardship, process stewardship and product stewardship
AIRBORNE CONTAMINANTS, NOISE AND VIBRATION	Effective use of water for dust suppression; radionuclide transport
CYANIDE MANAGEMENT	Managing risks of water contamination with cyanide
MINE CLOSURE	Overview of water risks and their management in post-closure phase

The aim of this handbook is to provide a guide to corporate management, site management and operational staff on a structured approach to water stewardship. It does not attempt to address detailed technical water management at the site operator level. A number of reference sources are available to support such detail, such as Younger et al. (2002) and MCA (1997).

Achieving leading practice may not be necessary in all aspects of a water management system. Resources (time, people, money) need to be prioritised to areas of greatest risk to the business and to the broader management of water in the catchment to ensure that management responses are fit for purpose and that resources are expended where they will have maximum positive impact. Each operation identifies risks based on their individual business cases. The operation's management should then select the leading practices that mitigate those risks and that best suit the economic drivers, catchment characteristics, and legal and sustainable development objectives. Leading practice operations make that selection by means of a risk-based assessment of key aspects of water management.

PART I: DRIVERS FOR WATER RISK

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 managing water is driven by the need to manage operational and strategic risks and opportunities.
- Of the mining and materials companies that reported to the CDP *Global water report 2014* (CDP 2014), 64% found exposure to water risk in their operations.[1] Almost half had experienced detrimental impacts related to water risk over the previous year, and 23% were exposed to water risk in their supply chains.
- Risks and opportunities must be managed at both the corporate and the site levels to ensure that shareholder value is maximised, production is secure, and the community and environmental values associated with the water are maintained or enhanced.
- Top-level site support and corporate leadership are the key to leading practice water management.

Water risk is not just about having insufficient water for site operations, but also about the challenge of managing large volumes of water as a result of flooding or dewatering. Water quality is an area of increasing concern, especially to communities and water-dependent environments in catchments that may be affected by operations.

For companies, poor water stewardship can result in financial exposure arising from delayed project approvals, constraints on production, property damage and tighter regulation. If water is poorly managed, access to ore and product quality can be compromised, resulting in higher operating costs and potentially a loss of market share. Sites with water issues require increased monitoring and auditing to achieve environmental compliance. This results in a greater management burden for the company and the potential to attract greater scrutiny from regulators.

Beyond the operation, a poor reputation for water stewardship can contribute to loss of investment attractiveness, shareholder value, and access to other resources (water, ore and land). Poor water stewardship can cause concern for local communities and other water users, and that concern can damage business reputation and erode the company's social licence to operate, which may be very expensive to remedy in the long term. The impacts of substandard water management might not only be felt at the local level but could escalate rapidly to become national and international issues and may be far more financially damaging than impacts at the operational level. Analysis has shown that companies that take action to manage water strategically are proving to be better financial performers (CDP 2014).

1 CDP is an investor-led initiative that works with 822 institutional investors holding US$95 trillion in assets to help reveal climate and water risk in their investment portfolios (https://www.cdp.net/en-US/Pages/HomePage.aspx).

Too often, site-level water management takes a short-term and reactive approach that is based on seasonal water availability and the immediate needs of the site. That approach raises the risk that management priorities will become closely tied to the current conditions and too tightly geared to one water balance scenario: that is, intense attention in times of scarcity or surplus and inappropriately low attention at other times. Operational planning timeframes are also typically short term, ranging from a year to two years. However, timeframes required to manage water risks are longer because they involve significant technical uncertainties, stakeholder and policy engagement, and the development of controls to mitigate or prevent water issues.

Thus, the consideration of risk requires that operational and strategic variables and their uncertainty are assessed over the mine's life cycle, including post-closure, rather than reacting to current and recent conditions.

Water stewardship is not solely an environmental management task. Operational and strategic risks associated with water management must be well controlled by a team sourced from all aspects of mine site operations. An integrated approach to water risk management is necessary, as multiple and interdependent water risks are likely to exist at operations or within mining regions. In particular, changes in the overall operational water balance may result in various water supply, storage and quality challenges manifesting over different timeframes. Leading practice in water stewardship requires a longer term, collaborative and practical approach that accounts for operational and strategic water risks to manage water resources responsibly.

This section outlines the drivers of water risks, including operational and longer term strategic risks. For a mining operation, three interdependent considerations must be managed at all stages of the life cycle to meet business and sustainable development objectives:

- Produce mineral commodities.
- Protect the ecosystems from which the operation extracts resources and into which it releases waste products or diverted water.
- Maintain the social and cultural values that the operation may affect.

The business case for leading practice water stewardship is based on the risks of failing to manage these considerations and also of failing to realise opportunities for improving performance. It is also related to managing the higher level strategic risks that may result for the company. Environmental regulation is becoming more stringent. Meeting compliance requirements and managing the business risk relating to water require a proactive business-wide strategy. Good water stewardship can also provide an opportunity to support new approvals, build relationships with external stakeholders, and secure the company's long-term social and regulatory licence to operate.

1.1 Drivers for operational risks

Operational-level risks result from inadequate understanding of technical water challenges, the failure to understand the uncertainty involved in developing solutions for complex water challenges, and inadequate planning that does not account for the longer timeframe required to mitigate water risk. Failure to avoid or mitigate and manage these risks results in impacts on water quantity and water quality and, in many cases, both at the same time. These risks have significant potential to disrupt or reduce production, increase production costs, and damage reputation with other water users, government and the community generally. These risks include the following:

- Insufficient attention to security of supply can result in water shortages, with associated reductions in revenue from loss of production, the payment of high prices for water when trying to purchase it in dry times, potential loss of market share due to perceptions of unreliability of product supply, or tensions arising from competition with other water users for access to water.
- Poor management of water excess can result in breaches of licence, environmental impacts and fines, as well as loss of community support for the operation in the event of uncontrolled discharge and dewatering impacts. When excess water is acquired from heavy rainfall, errors in storing the appropriate amount of water can compromise the viability of the operation in dry times.
- Inadequate attention to water quality management may result in reductions of mineral recovery, compromises of product quality or breaches of regulations (for example, the REACH provisions[2]), all of which will not be well regarded by the market. There may also be additional costs in managing excess poorer quality water on site. Personal health and safety may also be compromised if water for potable use is not properly treated or managed. Further, significant fiscal and reputational costs can be associated with a failure to manage the impacts of discharges of poor-quality water on aquatic ecosystems and on agricultural and recreational water values (fish kills, stock and human health impacts) within the lease and in the receiving environment. Equally, overuse of fresh or potable water when other fit-for-purpose water would suffice can undermine a company's reputation as a responsible steward of water.
- Inadequate consideration of water in closure plans may affect the company's finances or reputation. For example, water quality impacts or rebound of the watertable after dewatering can result in long-term liabilities if mitigations have not been well planned and implemented. A recent review of mine closure plans showed that many sites have relatively optimistic assessments and an inappropriate understanding of the technical uncertainty for the requirement to treat water after production shutdown (Byrne 2013). The review found that many companies included monitoring for only one to two years after the execution phase of closure. The increased focus on cumulative effects also requires longer closure timeframes to be addressed. In addition, some sites must manage water quality impacts in perpetuity, resulting in significant costs. Expectations about closure are growing, and regulators are setting requirements for sites to be returned to baseline conditions.
- Poor operational practices and resultant inefficiencies can lead to penalties and 'hidden' operational and capital costs, such as water volume charges and maintenance costs, energy costs associated with unnecessary water pumping and transfer on site, and expensive environmental legacies at closure. Impacts on ore accessibility and stripping ratios and changes to mine plans caused by water management issues can also result in additional operational costs.

2 REACH is Regulation (EC) 1907/2006 concerning the registration, evaluation, authorisation and restriction of chemicals.

1.2 Drivers for strategic risks

A number of longer term *strategic risks* emerge for mining companies if water management challenges are not effectively managed, if company reputation is compromised, or if company standards, values and ethics are not being adhered to. Strategic risks typically require mining companies to look beyond the mine gate to consider current and future risks at a catchment or regional scale. These risks can also affect operational success, stewardship and overall water resource sustainability. The reputational impacts of poor water management at one site can reflect on the whole mining sector. The financial implications of poor performance in managing the strategic risks can be much greater than the direct operational-level risks.

These risks include:

- **Increasing social concern:** Mining operations access water resources that are shared with local communities and other water users. Community access to sufficient water resources of the right quality is a recognised human right. Concerns about water often reflect the real impacts of mining activities on water resources but can also arise from communities' perceptions and expectations about water stewardship. Both need to be taken into account by companies as they develop their understanding of water risk and develop suitable long-term strategic approaches to minimise related risks and avoid or minimise impacts. Ultimately, the permission that society gives to industry to produce minerals (the social licence to operate) can be compromised, with serious implications for project viability and company reputation. The mining operation needs to engage with the local community and other stakeholders to understand their current and future water uses and the value those stakeholders place on water, and then incorporate that understanding into strategic and site water planning. The interaction between local communities and mine water management is very dependent on the local water context, so no single approach will suit all situations.
- **Increasing regulation:** Sites operate within consent and policy conditions that directly or indirectly affect water access, use and disposal within a catchment or region. Increased stakeholder interest in water is placing pressure on local, regional and national policymakers to develop more stringent controls on water use and wastewater discharge to protect the environment and surrounding communities. Increased regulation also eventuates through consistently poor water management from an individual mining company or a collection of miners within a state or mining region. This can increase the cost of managing water resources and limit opportunities for the development or expansion of mine operations.
- **Cumulative impacts:** The cumulative impact of site activities on regional water resources and the ecosystems they support is an area of growing concern and regulation. Cumulative effects of water management from multiple projects can affect social assets, as well as other water users. Uncertainty about how sites are affected, as well as about the most appropriate management and regulatory approaches for multiple contributors, presents a considerable challenge for companies, other water users and stakeholders. Fit-for-purpose solutions that consider long-term, catchment-wide, collaborative approaches are needed to appropriately manage current and future cumulative impacts.
- **Climate variability and climate change:** Climate change is expected to have significant impacts on water availability, water excess and water demand, although there is uncertainty about the magnitude and location of impacts. Changing water availability as a result of climate variability and climate change needs to be estimated, planned for and monitored. Relevant risks derive from the uncertainty about the magnitude of impacts and the frequency of major weather events with potential impacts on production and infrastructure. An additional challenge is how well regulation reflects uncertainty about impacts due to climate change and variability. Inadequate regulation may expose companies to regulatory breaches.

- **Investor scrutiny driving increasing disclosure on water risk:** Institutional investors increasingly require companies to disclose their water risk, including their social, environmental, operational and supply-chain risks. This is because those investors understand the link between water risk and the financial exposure of their investments due to water scarcity, flooding impacts or remediation requirements. This trend will continue to drive further disclosure on water management, moving from corporate-level reporting to site- and catchment-level reporting on water risk. Investors are currently developing new methods that they will use to publicly compare companies on the basis of water risk.
- **Water supply chain:** Water risks associated with procurement activity are an area of growing concern for many companies. Supply-chain risk examples include the water risks associated with energy supply and the water management credentials of major equipment and service suppliers. About 23% of the materials and mining sector reported exposure to water risk in their supply chain (CDP 2014), but less than half require their key suppliers to report water use, risks and management.

Tables 2 and 3 summarise the key operational and strategic risks for water management and their causes.

Table 2: Operational risks and opportunities associated with water management

TYPE OF RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	RISKS
Not enough water for mine operations (lack of security of supply)	• Poor planning—lack of understanding of supply reliability/capacity or demand estimation. • Change in legislative arrangements changes volumetric entitlements or access. • Lack of attention to meeting design efficiencies creates higher than expected demand. • Insufficient attention to climate and hydrological variability.	• Strategic control over water security provides regulator, community, customer and investor confidence in the operation, product or company. • Opportunities to outcompete and potentially purchase operations that become non-viable because of lack of water. • Infrastructure investment or co-investment to provide social and environmental value, as well as productivity benefits.	• Reduction in revenue from loss of production, payment of high prices for water in times of scarcity or potential loss of market share due to perception of unreliability of product supply. • Damage to reputation with other water users, regulators, customers, investors, the community generally, and workforce.
Too much water (e.g. flooding or large discharge volumes)	• Poor design or not operating to necessary standards to deal with surplus water results in environmental breach, safety or health incidents or loss of production. • Large discharge volumes damage offsite social, cultural, economic values.	• Possibility of supplying third-party users or water trading. • Potential social or environmental benefit (e.g. input to environmental flows). • Appropriate storage may reduce demand for raw water, thereby reducing costs 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.
Mine water operational constraints	• Ineffective dewatering, water storage and conveyance and an insufficient understanding of technical error and logistical uncertainty in water pumping management systems. • Poor planning for extreme events. • Poor planning for hydrological or climate variations.	• Water constraints and challenges inform or front-end-load the mine planning process.	• Loss of production. • Changes to mine plan increase operating costs and rehabilitation and closure liabilities. • Water shortages or quality impacts.

TYPE OF RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	RISKS
Water quality not fit for use in mine operations or water quality not suitable for discharge	• 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 or climate variations.	• Minimise water withdrawn from the environment via improvements to water quality through optimising site water management or investment in treatment. • 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 that will not be well regarded by the market (e.g. breaches of the REACH provisions). • Additional costs in managing surplus water on site. • Significant fiscal and reputation costs associated with impacts on the environment (onsite and offsite) and other users.
Discharge of mine water damaging offsite water quality	• Poor management of onsite surface water, stormwater, acid and metalliferous drainage, biofouling, tailings management and storage lead to offsite effects on water quality.	• Greater resilience and operational continuity due to surface water management during flooding (e.g. clean drains and water, sufficient storage areas) mean operation can remain in production. • Community content with (supportive of) other operations or expansions. • No delays on access or approvals.	• Breaches of licence resulting in fines. • Loss of production. • Loss of community support for the operation. • Site, company and industry reputation damaged.
Closure liabilities	• Poor water planning during operations or not taking into account changing circumstances. • Cumulative effects and impacts. • Acid and metalliferous drainage. • Tailings management.	• Significant reputation growth with successful closure. • Community supportive of other operations or expansions. • No delays on access or approvals.	• Poor reputation resulting in long-term (possibly permanent) liabilities and associated costs.

Table 3: Strategic risks and opportunities associated with water management

TYPE OF RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	RISKS
Investment attractiveness	• Company reputation is reduced due to poor water management. • Lack of attention to efficiency, environmental requirements, health and safety, security of supply.	• Company or mining industry seen as preferred investment proposition.	• Investors prefer other entities with similar financial returns but better reputation.
Access to resources	• Government and regulators prefer to provide access to resources (water, ore and land) to companies with reputation for good management.	• Access is given to resources without delays.	• Ore bodies may become unavailable or approvals may be delayed.
Infrastructure resilience and security	• Changing nature of extreme climatic events, such as size of extreme hydrological flows (e.g. flooding, tidal surge). • 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 or delay company or 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. • Recognising heritage and traditional owner spiritual and cultural connection to water.	• Industry viability, potential slowing of access to ore bodies or approvals, and difficulties with ongoing operational efficiency (loss of production time due to social disruptions).
Cumulative impacts	• Growing stakeholder concern, increased regulation and increased costs for sites that do not manage the cumulative impacts of site activities on catchment water resources and the environmental, social and economic assets they support.	• A long-term collaborative approach is needed to appropriately manage cumulative impacts, where required. If done well, this leads to positive relationships with stakeholders and improved reputation for the company and the industry as a whole.	• Tighter regulation, limitation on new water allocations and new entrants, and approvals delay.
Exposure to longer term changes in water availability	• Impacts on operations, increased costs and damaged relationships with other water users as a result of changes in water availability associated with climate variability and change (e.g. water excess and scarcity).	• Longer term planning and good understanding of water balance can provide operational resilience in times of water excess or scarcity.	• Lack of planning for water availability results in lost production and increased costs associated with flooding and water scarcity.

TYPE OF RISK	CAUSE(S)	IMPLICATIONS	
		OPPORTUNITIES	RISKS
Loss of investment attractiveness	• Impacts on operations, increased costs and damaged relationships with other water users as a result of changes in water availability associated with climate variability and change (e.g. water excess and scarcity).	• Investors see companies that disclose and manage water risks as their preferred companies to invest in.	• Investors choose not to invest in companies with poor water stewardship.
Financial exposure as a result of water supply-chain risks	• Investors are rating companies on water risk, as poor water management affects the financial exposure of their investments (e.g. costs involved as a result of water scarcity, flooding impacts or remediation requirements).	• Understanding of supply-chain water risks important to reducing potential exposures. • Gain recognition as a good water manager via engagement with key suppliers on water risk.	• Potential for operational impacts if supply-chain risks are associated with major suppliers. • Potential for reputational damage if a major supplier has poor water stewardship.
Workforce	• Employees perceive that the company is not managing water well or not providing them with sufficient amenity (e.g. safe drinking water, sporting and recreational 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.

PART II: WATER GOVERNANCE

Water governance encompasses the range of political, social, economic and administrative systems that are in place to manage water resources by governments, corporations and individuals. Historically, the primary authority for water allocation decisions in Australia has resided with the states under the Australian Constitution. The role of the Australian Government in the management and regulation of water has significantly increased over the past decade.

The regulation and management of water by governments is an area of ongoing reform. Accordingly, Section 2 should be taken only as a general overview of those arrangements, which may be subject to future change. As Section 3 describes, water governance also applies to the standards, systems and accountabilities for water in the individual company, as well as the processes needed to engage and coordinate resources and responsibilities between multiple stakeholders in a catchment.

The regulatory environment is moving towards requiring the consideration of impacts on a more regional or catchment scale, rather than the local site scale that was previously considered. Catchment-related water risks and planning are covered in sections 4, 5 and 6.

2.0 GOVERNMENT WATER REGULATION

Key messages

- 'Water governance' refers to the range of political, social, economic and administrative systems that are in place to manage water resources by governments, corporations and individuals.
- Primary responsibility for water in Australia remains with the states, where the rights to manage and control waters are vested in the Crown.
- The role of the Australian Government in the management and regulation of water has significantly increased since the signing of the Intergovernmental Agreement on a National Water Initiative (NWC 2004), which acknowledged the need for a national approach to governance for the efficient and sustainable use of water resources.
- The mining industry complies with government regulations plus a range of industry-led initiatives to manage water resources.

2.1 State and territory governments

Historically, responsibility for water rested with the states at Federation under section 100 of the Australian Constitution, in which the rights to manage and control waters are vested in the Crown. Statutes and supporting policy were, for much of the 20th century, developed separately in each of the state jurisdictions, although with some similarities in approach. This led to different jurisdictional approaches to managing water, which did not consider equity of access to water or integrated management and resulted in suboptimal management of rivers and aquifers that traverse state borders, most notably in the Murray–Darling Basin states.

Water management in the mining industry is not only covered by water resource planning regulation but more often resides in various minerals and mining Acts, environment protection Acts, and the various federal uranium Acts. Other regulators are important in defining how mine water management can occur. For example, agencies with responsibilities for mining regulation may have a role in determining regulations and guidance for tailings storage and management, as well as for water management at closure. Water allocation is not the only area for licensing activities, and companies need to understand the full range of water commitments in the various state and federal legislation covering their operations.

In 2004, the states and territories signed the Intergovernmental Agreement on a National Water Initiative (NWI) (NWC 2004).[3] Under the NWI, the signatory states and territories have achieved a growing alignment in their approaches to the allocation and management of water, and those approaches accord with a common set of principles to optimise economic, social and environmental outcomes.

State legislation remains 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, often in addition to water allocation and entitlement rules.

Despite greater alignment under the NWI, legislation, policies and administrative processes relating to water management vary between the states and territories, so an awareness of jurisdiction-specific requirements is necessary.

Approvals and licences may stipulate operating conditions, including quality, quantity and timing under which water can be accessed and discharged. Significant guidance on the application and derivation of compliance standards for water quality is provided by the National Water Quality Management Strategy (NWQMS).[4] State and territory regulators and industry use the guidelines to derive appropriate discharge criteria.

In most states, water allocation is carried out periodically through the interaction of a local coordinating group and state agencies. Allocations to the mining industry may be changed if hydrological conditions are deemed to have changed or previous estimates of sustainable yields are brought into question by new data or modelling. Industry representation in the water planning process is often via state industry associations.

Water plays a vital role in the environment and also touches on myriad aspects of human activity. As a consequence, various aspects of water management are included in a large number of government Acts, regulations and policies outside the primary water Acts. This can create regulatory overlap that adds complexity to the way the mining industry accesses and manages water.

3 Western Australia did not sign the NWI until 2006.

4 National Water Quality Management Strategy, http://www.environment.gov.au/water/quality/nwqms/index.html.

For example, the states exercise important environmental protection powers that can limit the way water can be taken and used if detrimental impacts to the environment are likely. Those powers take the form of project approvals and conditions, as well as licensing requirements for the discharge and release of water, irrespective of quality.

Until the National Water Commission was abolished in 2014, its triennial review, *Australian water blueprint: national reform assessment 2014* (NWC 2014a), summarised the water resource planning legislative framework for each state and territory and the jurisdiction's progress against the NWI commitments.

2.2 Australian Government

The NWI (NWC 2004) is the principal framework for national water reform and is central to the role of the Australian Government in the management and regulation of water. The NWI had its origins in the 1994 Council of Australian Governments Water Reform Framework, which acknowledged the need for a national approach to governance for the efficient and sustainable use of water resources (COAG 1994).

The key aims of the NWI are to improve the efficiency and productivity of water use by restoring overallocated water systems to sustainable levels and to enable the development of water markets by removing barriers to trade. Central to the NWI is a nationally consistent approach to the management of water access entitlements. It seeks administrative and legislative changes in all jurisdictions to accord with a common set of principles, primarily to limit permanent and adverse ecosystem change and to address uncertainty of supply for human use.

Clause 34 of the NWI recognises that the mining sector can face special circumstances that may require specific management arrangements that are beyond the scope of the NWI. This is in recognition of such factors as isolation, relatively short project durations, water quality issues and obligations to remediate and offset impacts. In recent years, the Australian Government and the minerals industry have collaborated to consider more closely the ways that the mining industry can integrate with the NWI.

In addition to the NWI, the Australian Government exercises control and influence over water regulation and management through the *Water Act 2007* (Cwlth). The Act, which is specific to the Murray–Darling Basin, gives the government oversight of water charging, trading and market rules for defined water resources.

The Australian Government has powers under the *Environment Protection and Biodiversity Conservation Act 1999* that can affect the way water can be taken and used. The Act is triggered wherever an activity is likely to have a significant on specific 'matters of national environmental significance'.

In 2013, a new matter of national environmental significance was established for coal seam gas and large coalmining developments that may significantly affect a water resource. Mining projects that fall in this category are subject to an Australian Government assessment and approval, which may include the consideration of cumulative impacts through the use of bioregional assessments.

2.3 Rights to waters and the Native Title Act

The *Native Title Act 1993* (Cwlth) recognises and protects rights and interests held by Aboriginal peoples and Torres Strait Islanders by providing a mechanism for the determination of native title over an area of land or waters. 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 exists 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 recognised by the common law of Australia.

Native title rights relating to water are usually non-exclusive and generally restricted to the right of use for personal, domestic or non-commercial communal needs, including the observation of traditional, cultural, ritual and spiritual laws and customs. Native title rights to water may exist over oceans, seas, reefs, lakes, rivers and inland waters that are not privately owned.

Some uncertainty as to the exact nature of native title rights and interests in onshore and offshore waters remains. Native title coexists with and is subject to any validly granted non-native title rights and interests in the native title area. The extent of any native title rights in a particular area depends 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.

Under the future acts regime in the Native Title Act, a number of different procedures are provided to ensure that actions that may affect native title ('future acts') can remain 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 those rights or interests. Grants of interests, permits or authorities allowing mining and mineral development activities are generally future acts that affect native title rights.

Operations need to engage with local Indigenous communities to manage issues of cultural concern, including water, that are not strictly dealt with as a legal requirement under the Native Title Act. Water and its flow through the landscape form a critical element of what defines the concept of 'country' for traditional owners. Mining operations need to consider appropriate means of engagement on water management that recognise and acknowledge the nature of this connection (see Section 5.2.2).

3.0 CORPORATE WATER GOVERNANCE

Key messages

- Water governance refers to the range of political, social, economic and administrative systems that are in place to manage water resources by governments, corporations and individuals.
- In a company, governance can be defined as the set of authorities, processes and procedures guiding the organisation's decision-making.
- Governance also extends to the controls set at a site level to ensure that operations implement water programs and meet performance and compliance objectives.
- Successful water management requires senior management accountability, company water objectives need to be mandated, and accountabilities and performance measures need to be clearly set to deliver effective outcomes.

Water governance includes the standards, systems and accountabilities for water set by an individual company, as well as the processes needed to engage and coordinate resources and responsibilities between multiple stakeholders in a catchment.

In a company, governance can be defined as the set of authorities, processes and procedures guiding the organisation's decision-making. The company's board, which is ultimately responsible for the mining operation, sets expectations for how water is managed. Clear objectives, systems and accountabilities are required for the company to comply with its water commitments. This includes the legal and licence requirements for water resources and environmental protection either set in legislation for all operations or established as part of the licence conditions at the time the operation's activities are formally approved. It also includes internal company standards and voluntary commitments made as part of various regional, national or international water initiatives.

Governance also extends to the controls set at the site level to ensure that operations implement water programs and meet performance and compliance objectives, such as compliance with a mine development schedule to prevent costly uncontrolled deviations from the plan. Operations need to carefully consider appropriate lead-time planning, operational designs and improvement processes that consider the multiple water risks, interfaces and governance structures. Ultimately, successful water management requires senior management accountability, and company water objectives need to be mandated and accountabilities and performance measures clearly set to deliver effective outcomes. Section 7 provides a practical overview of the importance of setting clear objectives and taking a risk-based approach to operational water management.

3.1 Building organisational capacity for water stewardship

As discussed in Section 1, the drivers for water risk have become more complex as competition for water resources has increased and mining companies encounter greater technical challenges in water management. Companies now need to manage their site activities and their impacts beyond the mine gate and to engage with concerned stakeholders and policymakers on the best way to manage water resources.

Mine water management spans a number of functional boundaries, including the environment, processing, engineering, mine planning, the community, and government relations. Mine water management can also be fragmented, extending across individual or multiple sites within a catchment. An integrated approach to water management needs to be developed so that water objectives, programs and accountabilities are clear and roles and responsibilities are understood by different functions and sites.

To mitigate operational and strategic risks, businesses need to coordinate internally across multiple functions or departments, as well as to engage with external stakeholders, such as the community and governments. Collective management does not mean that accountabilities and responsibilities for particular areas cannot be assigned. Table 4 provides an overview of the different operational tasks that involve water and the functional areas responsible for them. Note that some overlaps exist between groups and that people's responsibilities will vary according to site requirements.

Table 4: Typical tasks and responsibilities for each of the teams managing water in a mining operation

AREA	TASK
Corporate	Develop a company water strategy to provide medium- to long-term direction on water and linked to other business processes (e.g., compliance, company standards, auditing and reporting). Engage with government and other key stakeholders on water management and regulation. Develop appropriate standards and targets to drive corporate water management performance.
Site water team	Appoint a suitable decision-maker, with appropriate seniority, to take accountability for water. Develop site water conceptual model and water balance. Provide water risk assessment and management for operational and catchment-related water resources. Develop and implement a site water strategy and plan. Include representation from key site functions with water accountabilities. Prioritise site water risks. Engage suitably qualified staff. Coordinate the implementation activities across the site to mitigate water risks. Engage stakeholders on catchment-based and site-based water issues. Report progress with implementation to site general manager.
Mining operations	Develop site water management plans. Engage stakeholders on catchment-based and site-based water issues. Manage storages, roads and drainage to meet licence regulatory requirements. Manage water supply and demand. Implement pit and advance mine dewatering. Prepare and implement flood and drought management contingency plans. Provide dust suppression (typically roads, stockpiles and conveyors). Provide vehicle wash down (minor). Undertake building and maintenance works. Implement closure—water and tailings. Provide fire water and potable water. Provide engineering and environmental monitoring and reporting.

AREA	TASK
Mineral handling and processing	Separate mineral and gangue materials. Manage tailings and reject material. Manage process water and recycling. Provide dust suppression—stockpiles, conveyor and drainage of industrial area. Provide engineering and environmental monitoring and reporting.
Environment and community	Undertake rehabilitation planning. Undertake closure planning. Provide water flow, discharge and quality monitoring, reporting and assessment. Provide environmental monitoring, reporting and assessment. Provide onsite and surrounding ecosystems management. Participate in regional and local water planning. Engage with traditional owners, non-government organisations, and other key stakeholders. Provide corporate reporting—internal and external.

Leading practice involves water management that is integrated across multiple departments through a coordinating governance body or water stewardship champion. The governance body or champion provides leadership for water and coordinates actions across multiple operational functions to address long-term, high-risk water management issues. The chair of the governance body or the water champion needs to be someone who understands the range of water risks, technical and regulatory uncertainty, operational practicality and logistical challenges, and who is capable of influencing operational and planning outcomes.

The investment in water governance by a company will depend on the level of water risk it faces and the size of the business. In large businesses where water is a significant risk, leading practice requires a water governance body and water champion at the company level and/or business level with representation from all relevant departments to confirm water roles and manage responsibilities. In smaller businesses, water can be managed by a site water champion and included as a key agenda item in existing operational or environmental committees.

Among other duties, the governance body or water champion is responsible for developing the long-term water strategy (see Section 7), as well as for making decisions, coordinating actions across multiple operational functions, and communicating with and monitoring the appropriate managers to address long-term, high-risk water management issues.

At the site level, it is essential to have a water team that is focused on implementing the site water strategy via the operational water plans. The team has representation from across the site and works with operational areas to implement the required water program. This level of water coordination ensures that there is no duplication of services, there is more effective planning and coordination across departments, and risks are more clearly identified, resulting in more effective water management programs. Specific water service or operational delivery activities (such as mine dewatering teams) are typically best located in the service or delivery area, and the consolidation of water functions into one operational department is rarely considered appropriate, as organisational structures should be optimised for the core business of mining. For example, the operation of borefields should be managed by the team accountable for delivering water supplies and not by an environmental department.

Site personnel also require ongoing training and support to build competence in their water management accountabilities. For example, they need to understand:

- how to develop a conceptual site model for their surface water and groundwater resources
- how to manage the site water balance and how to use it to validate site information
- water quality criteria and reviews of sampling programs
- how operational water management fits with the company's or site's long-term water strategy
- how to engage with stakeholders on water.

Companies also need to build capacity in their understanding of the regional water resources and potential impacts by investing in research on key water risks and by developing focused partnerships with organisations that have expertise in the area. These aspects can also form key elements of a company or business water strategy.

3.2 Voluntary commitments on water

In addition to working within the regulatory bounds for managing the taking, use, discharge and quality of water, mining companies commit to various voluntary initiatives on water at the national or international level to improve water stewardship. Peak mining industry bodies at state, national and international levels have become involved in collective industry initiatives that have led to the industry becoming increasingly willing to engage on water stewardship issues. Also, a number of influential water initiatives at the global level are driving the expectations of shareholders, financial institutions and other stakeholders about water performance.

3.2.1 Industry water initiatives

In 2014, the International Council on Mining and Metals (ICMM) released its Water Stewardship Framework (ICMM 2014), which establishes a direction on responsible water stewardship for member companies, including many in Australia. Importantly, the framework promotes a holistic approach to addressing social, environmental, operational and economic aspects of water management, with a strong focus on the importance of developing a catchment approach to understanding and managing water risks. The framework provides guidance for companies on transparent reporting, inclusive engagement with communities, catchment approaches, and the development of site water management plans and water balances.

Case study: ICMM Water Stewardship Framework

The ICMM's Water Stewardship Framework outlines a common industry approach for water management and recognises that water connects an operation to the surrounding landscape and communities. ICMM (2014) sets out the rationale and key elements of the framework:

> Water is one of the most significant issues facing the mining and metals industry and is a critical resource not only for all our members' operations but also for other industries, communities and the natural environment. Water stewardship requires a management approach based on finding solutions that work for the business and those other water users.
>
> ICMM's Water Stewardship Framework is built around four key elements:
>
> 1. Be transparent and accountable
> 2. Engage proactively and inclusively
> 3. Adopt a catchment-based approach
> 4. Effective water resource management.

Underpinning each element is a set of supporting activities that companies can undertake. The extent to which they are required and implemented depends on the level of risk and opportunity at the local level. Progress in implementation will be reported.

ICMM acknowledges that each member company is at a different stage of the water stewardship journey. This framework provides a common direction, a consistent point of reference and a shared language for member companies to continue their water stewardship journey together.

Water is also a major area of focus for the Minerals Council of Australia (MCA). Since 2012, MCA member companies have been committed to a consistent method of publicly reporting on key global water metrics as part of the MCA's increasing focus on water accounting (MCA 2015). The metrics are focused on water inputs and outputs and aligned with the Global Reporting Initiative. The focus on water accounting is to ensure that industry reports on water inputs and outputs in a transparent and consistent manner. This approach also allows industry to review and improve site water management practices. The MCA Water Accounting Framework for the Minerals Industry (MCA 2014) has since been expanded to incorporate accounting for varying water qualities, and this will be adopted by member companies over the coming years. Water accounting is further discussed in Section 11.2.

Industry also supports water research by a number of organisations to better understand the risks arising from water shortage or surplus, water quality impacts, and the risks and opportunities related to social and environmental effects of mining operations and legacies. For example:

- the Centre for Water in the Minerals Industry within the Sustainable Minerals Institute of the University of Queensland was established in 2004 as a water research centre funded jointly by industry and government
- the Australian Coal Association Research Council is a coal industry funded organisation that supports research into coalmining, including water management
- the Minerals Tertiary Education Council is a division of the MCA and promotes the development of world-class education for mining and technical professionals.

Companies also support various cooperative research centres (CRCs) related to water; for example, CRC CARE delivers industry-focused technologies and guidelines for the assessment and clean-up of contamination.

3.2.2 Global water initiatives

Water is increasingly recognised as a material risk by many companies. Many water management initiatives, methods and guidelines are being developed by organisations, including the financial sector, to help companies manage water risk. The challenge for many companies is to understand which tools are useful or practical in setting future standards for water management.

Increasingly, many initiatives are starting to address the operational and strategic issues faced by sites, rather than just recommending targets for water use reductions and water quality improvements. Although the latter are sound water management objectives, they may not always represent the broader challenges faced by mining operations and other stakeholders in their catchments.

The following are four of the more prominent global initiatives:

- The **CDP Water Project** represents 822 institutional investors with around US$95 trillion in assets that are promoting greater transparency on corporate water issues. An annual survey sent to companies covers all dimensions of water risk, including operational, social, environmental, financial and supply-chain risks. This organisation is planning to publicly rate companies on their water risk.[5]
- The **World Business Council for Sustainable Development's Global Water Tool** helps companies to map their water use and assess risks relative to their operations and supply chains. It compares the company's sites with the best available water, sanitation, population and biodiversity information on a country and watershed basis.[6]
- The **Alliance for Water Stewardship** is a draft global water certification scheme for companies that aim to promote good water management practice. It takes a catchment-based approach to understanding the risks and encourages the site to have a strong role in engaging at the catchment level and influencing responsible water management outcomes.[7]
- The **CEO Water Mandate** is a United Nations led initiative designed to assist companies in the development, implementation and disclosure of water sustainability policies and practices. To date, it has focused more on translating good practice via member workshops and water reporting approaches.[8]

5 CDP Water Project, http://www.cdp.net.

6 World Business Council for Sustainable Development, Global water tool, http://www.wbcsd.org/work-program/sector-projects/water/global-water-tool.aspx.

7 Alliance for Water Stewardship, http://www.allianceforwaterstewardship.org.

8 CEO Water Mandate, http://ceowatermandate.org/disclosure.

PART III: CATCHMENT WATER MANAGEMENT

Water is a shared resource, and site managers need to understand their own water use, potential impacts on the catchment and risk shared with other stakeholders in the region in terms of water governance and water resource management. Catchment and regional dynamics are increasingly included in regulatory approaches and required for mine site water management (Section 5). For some companies, the challenge is to gain access to sufficient water of the right quality for site activities in a region with a number of competing users (including different industries, the environment and the community) and the potential for reduced allocations in the future. For other companies, operating in more remote areas away from competing industries, the concentration of mining activity in the catchment has grown, leading to broader catchment challenges, such as cumulative impacts associated with water use, water quality and discharge (Section 6). While Part III of this handbook provides an overview of catchment-related planning and hydrological risks, Part IV looks in detail at managing the interaction of the catchment with the operational mine water system.

4.0 REGIONAL AND CATCHMENT WATER RISKS

Key messages

- Water is a shared resource. and site managers need to understand their own water use, potential impacts on the catchment and risk shared with other stakeholders in the region.
- A catchment-based approach takes a holistic view of water management at the catchment and regional levels to help identify material water stewardship risks and opportunities.
- The high degree of complexity and interconnectedness of water risks requires companies to lead or participate in collaborative approaches with stakeholders to identify and manage the risks and opportunities on a catchment scale.

The high degree of complexity and interconnectedness of water risks requires companies to have a greater understanding of regional water resources and, where appropriate, to participate in collaborative approaches with other water users to identify the risks and opportunities and to secure a solution for water management challenges. The need to consider and manage for circumstances beyond the mine gate (and often to consider factors outside the mine's direct control) introduces a level of complexity and uncertainty that has significant implications for the way mines plan and operate.

It also means that mine operators need to be aware not only of the geographical extent of their operating context, but also of potential changes over time. Temporal changes could include changes in the way other users are managing water, changes in the expectations and perceptions of regulators and other key stakeholders, or changes in the way climate change and climate variability affect the catchment. This need for a wider awareness poses some significant challenges for mining operations in the way they manage water in the context of the catchment, the way they plan for the longer term with these dynamics in mind, and the way they engage with key stakeholders in the region or catchment.

The ability to manage the longer term risks (5, 10 or 20 years or more) associated with regional- and catchment-level dynamics is challenging, as companies' mine planning horizons are relatively shorter term (1, 2 or 5 years). This is even more difficult in challenging economic circumstances, when companies focus on minimising costs and maximising efficiency.

In an operating environment that is becoming increasingly linked to the water management actions of others, stewardship becomes a collective responsibility not just for the mining operator but for all the water users in the catchment. Furthermore, a failure by one mining operation to manage water responsibly will reflect on the reputation of the industry as a whole and particularly on other operations in the same region or catchment. A key challenge for mining operations then becomes striking the appropriate balance between water stewardship across the catchment and ensuring that those efforts are proportionate to the risk posed by the mine's water management activities and their impacts.

4.1 Catchment-based approach

A catchment-based approach takes a holistic and integrated view of the impacts of water management at the catchment and regional levels to help to identify material water stewardship risks. This approach considers key water assets, as well as assets of high environmental, social and economic value that may be affected by water management. It considers existing water users and, as much as is reasonably foreseeable, future water users and conditions. All components of the hydrological water cycle, including surface water and groundwater resources, need to be considered for responsible water management.

The ICMM has identified the adoption of a catchment-based approach as a key element of its Water Stewardship Framework (discussed in Section 3). To support this work, *A practical guide to catchment-based water management for the mining and metals industry* (ICMM 2015) seeks to enable a better understanding of the relevance and benefits of adopting a catchment-based approach to water risk management and to assist companies to define and deliver their own water risk management strategies that accommodate the particular characteristics of individual mines and catchments.

Catchments are not always easily defined. Surface water and groundwater interaction can often blur the definition of a catchment. In some locations, the terrain does not lend itself to clear identification of catchments. However, the important underlying principles in the catchment-based management approach are that mining operations are cognisant of the local and regional context within which they operate and that those considerations are factored into the risk assessment for their site water management.

4.2 What is a catchment-based approach to water management?

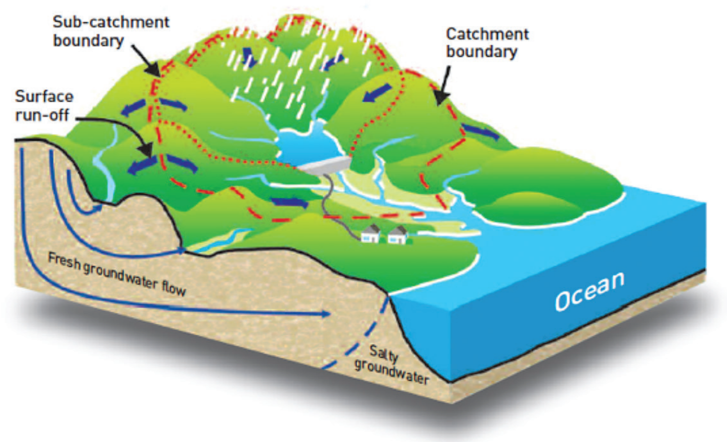
Taking a catchment-based approach to water management helps conceptualise and manage complex water resource challenges.[9] Such an approach looks at activities and issues in the catchment as a whole, rather than considering different aspects separately. It requires a diverse range of processes to be considered, including hydrology and land use, as well as broader political, economic, social and ecological dynamics that influence water use, water availability and water quality. It encourages organisations to consider holistically how competing demands on water resources from a range of stakeholders (domestic water users, industry, regulators, politicians) can create pressures and lead to conflict if not appropriately managed. It also requires that people from different sectors be brought together to identify issues, agree on priorities for action and ultimately build local partnerships to put those actions in place.

9 This section is based on ICMM (2015:15).

Mining and metals activities affect water resources, but are also affected by activities in the catchment that may be beyond their direct control. It is clear that mining and metals operations, by virtue of both their physical footprint and their use of water through extraction, processing and operational discharge processes, can change catchment dynamics. However, mining and metals companies can also be affected by physical and socioeconomic dynamics in the catchment.

Catchment characteristics such as water availability, quality and withdrawal rates can all affect mining and metals operations. While these dynamics may seem obvious, they are complex and require a relatively sophisticated understanding of the multiple and competing pressures on water resources from a range of users. Social pressures, developmental priorities and national, regional or local policy changes may also affect the operation. The catchment-based approach to water management seeks to draw attention to the complex nature of water risks and identify response options in instances where risks arise, or require action, outside the operational boundaries of the mine.

Figure 3: Diagrammatic example of a catchment



Source: Adapted from the North and South Rivers Watershed Association website (http://www.nsrwa.org), as cited in ICMM (2015:15).

5.0 CATCHMENT PLANNING AND KEY STAKEHOLDERS

Key messages

- Regional and catchment management recognises that water is a resource shared between users and the environment, today and in the future.
- Increasingly, the regulatory focus is on mining impacts and their water management practices at the regional and catchment scales.
- In addition to the statutory requirements placed on the water management of a mining operation, institutional arrangements in the catchment can play an important role in the way those requirements are applied, interpreted and enforced.
- Governments and catchment agencies are dynamic in their policy development, and mining operations need to engage with relevant agencies early and often.
- Stakeholder engagement and participation are means of recognising issues of concern and the varying perceptions of how well water management is carried out by the mining operation.
- Water and its flow through the landscape form a critical element of the concept of 'country' for traditional owners. Mining operations need to consider appropriate means of engagement about water management that recognise and acknowledge the nature of that connection.
- Mining companies need to recognise the broader linkages and tensions between their use of water and the use of water by other sectors, such as energy and food production, and to factor those interactions into the assessment of risks for water management in the catchment setting.

In the past two decades, there has been an emerging regulatory focus on regional and catchment-scale impacts (that is, at a spatial and temporal scale greater than individual mining operations). Where mining activity has become increasingly concentrated or where competition for the water resource with other water users has increased, this focus has led to a closer scrutiny of the impacts of mining operations and their water management practices on the catchment scale.

The concept of catchment-based assessment of water resources is central to the NWI (NWC 2004). Recent legislative changes pursuant to the NWI have given statutory recognition to the need to provide water for environmental purposes as an important part of defining catchment allocation limits and the amount of water available for consumptive purposes.[10]

A number of other factors have contributed to the development of a greater catchment focus in regulation. They include the emergence of biodiversity and ecosystem services as influential concepts in valuing the contribution of ecosystems to human welfare and the consideration of the impact of human activity on the ecosystem's health and its ability to continue to provide these services. The *Biodiversity management* leading practice handbook (DIIS 2016) discusses many aspects of managing biodiversity that are equally relevant in the water stewardship context.

10 See Section 6.7 for more on environmental flows.

Biodiversity management recognises the importance of the totality of genes, species and ecosystems within a region. This is important for ensuring ecosystem resilience and for maintaining an ecosystems services approach that lends itself to the consideration of key interactions within ecosystems and of human impacts on ecosystems at the catchment scale. An ecosystems approach involves a requirement to consider relationships at a multidisciplinary level, such as by recognising the connections between ecosystem health and cultural services (such as recreational, aesthetic and spiritual activities).

The emergence of these two concepts has resulted in regulators seeking to regulate regional- and catchment-scale impacts through a focus on individual mining operations. For example, regulators have sought to manage biodiversity impacts through the development of offset policies. Those policies seek to identify impacts on the amount, type and quality of habitat affected by a development and to offset the net effect through financial or in-kind compensation that will lead directly to long-term improvements in biodiversity and that are most often linked to the types of habitats affected.

More recently, regulators have considered how multiple water managers may need to jointly manage impacts on regional-scale assets. The concept that multiple operations, whether solely mining or mining in combination with other economic activities, can have cumulative impacts is gaining greater currency. Environmental regulators commonly require proponents to account for impacts on environmental assets that result from the incremental impact of a proposal when added to other past, present and reasonably foreseeable future proposals. This is a complex task, as it may require access to assets located off the mining lease and access to information that is not in the public domain.

When it comes to avoiding impacts to an asset of importance or taking mitigating actions to minimise impacts, the ability of a single impactor to manage cumulative impacts may be limited. Recognition is emerging of the need to better facilitate collaborative responses to cumulative impacts in which impactors assume collective responsibility for managing impacts. While the need to manage for the specific array and concentration of high-value assets within a catchment should drive the development of an appropriate, fit-for-purpose pathway for managing those types of impacts, the ways and means to facilitate collaborative responses to cumulative impacts are still relatively immature.

Nevertheless, the concept of cumulative impacts emphasises the need for project proponents to develop a sophisticated understanding of the environmental assets within their catchment and of the way their project may interact with other water uses within the catchment to affect those assets.[11] Developing this understanding does not necessarily require exhaustive surveys of the region. Requirements to understand the cumulative impacts of a new project should be proportionate to the environmental assets at risk, and so efforts to understand catchment impacts should centre on how those assets are affected by catchment hydrology and flows, the timeframe in which impacts may be observed, and how they may affect biodiversity and ecosystems service.

Because economic activity and catchment hydrology are highly dynamic, the regulation and management of cumulative impacts need to be able to adapt to them. Uncertainty about the nature and extent of cumulative impacts tends to drive a precautionary approach to regulation. It is therefore important to ensure that the regulatory regime identifies uncertainties as they relate to agreed high-value assets and seeks to put in place initial approaches using incomplete information.

11 See Section 8.5 for a discussion on cumulative impacts and the interaction between the operational mine water system and the catchment.

Adaptive management approaches (discussed in Section 7) can manage the dynamics and uncertainties while building knowledge over time by driving increased monitoring and investment in research and development where environmental assets are at risk of being damaged. Adaptive management approaches are not new. However, there is a need to explore how a collaborative approach with other companies, regulators and key stakeholders can effectively manage cumulative impacts via adaptive management.

Another approach to managing cumulative impacts that has had some success is through market mechanisms in which the ability to cap and trade 'rights to impact' builds in an incentive to reduce impacts. This has been most prominent in the Upper Hunter Valley Salinity Trading Scheme (see case study). This approach suits circumstances that support a market (that is, there are enough buyers and sellers) and where a cap or a limit can be defined. This approach is suited to managing impacts on a single receptor, but is limited in its application to manage impacts on multiple assets.

Case Study: Hunter River Salinity Trading Scheme—managing cumulative impacts

The Hunter River Salinity Trading Scheme is a unique market-based mechanism designed to manage the cumulative impacts of industrial activities on salinity levels in the Hunter River.

The upper Hunter Valley in New South Wales is home to extensive coalmining, coal-fired power generation, and a diverse agricultural industry, parts of which rely on the Hunter River for irrigation. Coalmining companies in the region include Glencore, Peabody Energy, Coal and Allied, Anglo American and BHP Billiton.

The Hunter Valley catchment is naturally saline. While more than 75% of salinity in the Hunter River is a result of natural processes, industrial activity such as mining and power generation contributes around 10% to 20% of the river's salinity. Coalmining in the region often intersects saline aquifers and exposes saline rock to onsite run-off. While saline water can be used onsite for purposes such as dust suppression, excess water occasionally needs to be discharged. Coal-fired power generators use river water for cooling and steam production, leading to a concentration of saline water, which may also require discharge from the site.

Before the scheme was introduced, industry was licensed to discharge low volumes of excess saline water continuously. However, this led to increasing salinity levels in the river during low-flow periods, resulting in impacts on agriculture, such as reduced pasture and crop growth.

The Hunter River Salinity Trading Scheme was developed to limit the discharge of saline water to periods of high river flows when background salinity levels are much lower and the discharged water is quickly diluted. The total amount of salt that can be discharged during these periods is also capped to ensure that salinity targets are met.

To discharge water into the river, an operation must hold salinity credits. The 1,000 tradeable salinity credits under the scheme are valid for 10 years. Every two years, 200 credits expire and another 200 are sold at auction. Each credit allows the holder to discharge 0.1% of the total allowable discharge of salt, which is calculated based on the river flow rates and background salinity levels.

The scheme was formally introduced in 2002, following trials and a pilot scheme. A review of the scheme conducted in 2014 found that, since the scheme began, salinity targets have not been exceeded except following extended dry periods when salinity was primarily sourced from diffuse or natural processes, such as from groundwater.

Hunter River and surrounding catchment.

Source: NSW EPA (2013).

5.1 Catchment-based institutions

Institutional arrangements in the catchment or region can play an important role in determining how statutory requirements for water management are applied, interpreted and enforced. Government agencies and departments with an interest in water management can further define operating conditions through regulations, by-laws, guidelines and policies, many of which can be region or even catchment specific.

The agencies and departments develop and interpret policy dynamically. They anticipate emerging water management trends and policy challenges and respond to specific circumstances as they arise. Their functions and their personnel change over time.

Sometimes, new technologies or new approaches to water management can expose uncertainty over regulatory responsibilities or, conversely, areas of regulatory overlap. The total effect of these institutional interactions sets the context within which mines must operate. The context not only confirms the water management requirements as they apply to the catchment or region, but also sets the conditions within which other stakeholders in water management develop and determine their expectations.

Mining operations need to carefully consider the catchment and regional context within which they operate, identify the related water management risks and provide both sufficient resources and clear accountabilities for functions relating to risk identification and response. Indeed, these dynamics should also be considered at the mine planning stage to ensure that these factors do not present a fatal flaw to the project and to ensure that options are identified early to account for them.[12]

Where regulatory responsibilities are uncertain or changing, mining operations need to engage with relevant agencies early and often and to work with them on appropriate water management responses. It is also appropriate in those circumstances to volunteer to share mining industry experience on appropriate regulatory change.

Catchment and institutional arrangements extend beyond the regulatory agencies that have direct involvement in mine water management. Environmental regulation for managing the potential impacts resulting from the way water is abstracted, managed and disposed of is important, but other regulators are also important in defining the limitations or the extent to which mine water management can occur. For example, agencies with responsibilities for mining regulation may have a role in determining regulations and guidance for tailings storage and management, as well as for water management on closure. Health agencies may also play a role in impacts on water quality, especially where water to be used for drinking may be affected. Similarly, public and private water utilities involved in providing drinking water and wastewater services within the catchment may have specific by-laws, guidelines or policies that need to be considered when planning and managing water for mine operations.

Mining operations should also be aware of other federal and state agencies that have interests in the catchment or region. For example, the interests of other industries that share the available water resource with mining, such as agriculture, are represented by their respective government agencies, and those agencies may be influential in decision-making and planning for water resources but may not have the specific needs of mining foremost in their mind. Many regions are also represented by active regional development agencies, whose interests are to promote the economic and social development of the region. Those agencies are often central to region-specific economic development initiatives that may have some bearing on the water management interests of an individual mine.

Local governments can play a multifaceted role in water management and planning in certain catchments. Planning, drainage and the provision of drinking water and wastewater services are all facets of catchment water management that need to be considered and that may be governed by local regulations and by-laws.

Australia is also characterised by catchment management bodies (known in some states as natural resource management boards), which vary widely in their names, structures, functions, powers, reporting and resourcing arrangements, depending on the jurisdiction. All these aspects of catchment management bodies are subject to considerable and rapid change, so it is advisable to seek the advice of the relevant state government administering agency on their relevance to the catchment and to the water management tasks to be undertaken by the mine operation.

12 See Section 8 for more detail on the interaction of the operational mine water system with the broader water resources of the catchment.

5.2 Regional and catchment management planning

Most regions and catchments in Australia are subject to regional- and catchment-scale management planning. Regional and catchment management plans commonly adopt long time horizons of 10 or more years, with periodic reviews during the life of the plan. The plans help to assess the present and the desired situation for water quantity, water quality, environmental integrity and economic development goals and often put forward a comprehensive set of measures to reach the desired situation. Those measures can include defined catchment allocation limits, approaches to water allocation, such as licensing or the issue and trade of water access entitlements, and agreed responses to seasonal availability. Other measures include monitoring arrangements, penalties and sanctioning, communication protocols, and conflict resolution and appeal procedures.

Mining operations need to be aware of the opportunities afforded by regional and catchment management plans to better inform the identification and definition of catchment risks for their operation and to ensure that such plans make adequate allowance for current mining operations and future developments. For many mining operations that operate in catchments that are isolated and where the water resource is not fully allocated, regional and catchment management plans provide a useful context for considering catchment-level risks. Plans synthesise relevant catchment information (including hydrological information), identify issues of highest risk and management priority, and indicate emerging issues relevant to the catchment, including evolving regulatory requirements. Where a mining operation is located in a fully or almost fully allocated system, the operation will need to engage in catchment planning to ensure that its interests are properly considered.

At its most complex, regional- and catchment-scale management planning reaches the scale and level of detail exemplified in the Murray–Darling Basin Authority's Basin Plan, which covers one of the largest river systems in the world and crosses the jurisdictions of four states and one territory (MDBA 2012). The plan provides a coordinated approach to water use across the basin, seeking to achieve a balance between environmental, economic and social considerations, and is specifically enabled by the *Water Act 2007*.

5.3 Key catchment stakeholders

Regional and catchment management recognises that water is a resource shared between users and the environment, today and in the future. The way water is managed can also have impacts on social, environmental and economic assets. Mining operations rarely operate in isolation, and the impacts of their water management practices, both real and perceived, need to be considered and shaped with that wider context in mind.

Increasing publicity surrounding water allocations across Australia, awareness of the consequences of extreme droughts and floods, concerns about water quality impacts, and discussion on climate change and climate variability have focused community attention on water availability and water quality and on where and how water is used. Therefore, mining operations have an increasing need to adequately resource the identification and management of water-related risks in a way that acknowledges this connection to the broader catchment and region.

In the 2012–13 national water account, the minerals sector was responsible for less than 2.9% of Australia's net water consumption (ABS 2013). While a relatively small user at the national level, mining can be a significant user of water or have significant impacts at local or regional levels. For example, in Western Australia, mining accounts for 36% of total licensed volumes (including surface water and groundwater) (DoW 2014).

On a purely value-adding criterion (dollars generated per megalitre of water used), mining and minerals processing add significantly more financial value than most agricultural uses (ACIL Tasman 2007). However, as water markets have become entrenched, some specific crops in certain catchments are now also achieving high levels of value-adding to the water being used (Morison 2014).

The concentration of the mining industry's water use in a region or catchment is important in shaping stakeholders' perceptions of responsible use and the appropriate sharing arrangements between multiple users, including the environment. Regional and catchment-level impacts on the water resource and the combined impacts of water management on regional environmental, social and economic assets require recognition and response.

Stakeholder engagement and participation are means of recognising the varying perceptions how mining operations manage water, and genuine engagement is a condition for achieving effective water resources management. Measures taken without the involvement of the beneficiaries or the affected have a reduced chance of success.

Stakeholders can be very broadly defined. They include those who are direct, indirect and potential water users; regulators and other relevant government agencies; local communities; traditional owners; and non-government organisations with an interest in the impacts of water management practices. The identification of key stakeholders requires careful assessment of what assets may be affected (or even perceived to be affected) by the water management practices of the mining operation, followed by the determination of an engagement strategy that is proportionate to the stakeholder risk.

Water has multiple uses and varying values to other users and other stakeholders. The earlier that key stakeholders can be engaged and, where appropriate, integrated into water management decisions or management actions, such as monitoring, the more stakeholder engagement and participation can be tools for avoiding or managing conflict. Earlier integration holds the greatest prospect for resolving potential conflicts.

A framework is needed for reconciling competing demands, such as agriculture, domestic water supply, the environment and recreation. In many instances, reconciliation is achieved mainly through markets in formal water property rights and the development of water-sharing plans in line with current national and international policy priorities. In a growing number of regions, catchment management plans are providing the basis for that framework.

5.3.1 Other water users

Other water users in the catchment are key stakeholders for mining operations. They may be other mining operations, other industries (such as agriculture and pastoral operations), or water utilities accessing water for supply to households for drinking water or to industry. The environment is also a water user. Water-use and allocation decisions often have to deal with the allocation of a scarce water resource between competing users. State statutes define how and the circumstances in which allocations are made to the environment, to stock and domestic water, to water for human consumption and, under certain conditions in some jurisdictions, to agriculture and industry.

In catchments where the water resource is at or close to full allocation, the NWI has sought to encourage the development of arrangements that set aside an environmental allocation and then allocate the rest of the resource for consumptive use using market mechanisms. This approach is based on the principles that, through the trade of water rights, water will flow to its higher value use and that the market will encourage efficiencies in water use that will result in water savings being made available to other users. Mining was originally considered as an interception rather than as a holder of tradeable water rights in water markets. However, work by the MCA together with the National Water Commission has sought to better understand how mining companies in these circumstances might engage more directly in water markets in the future (NWC 2014a, 2014b).

Where a market is able to manage the allocation of water and water rights, an understanding of the needs of other water users, including competitors, can inform decisions on measures to improve water-use efficiency, water recycling and the use of fit-for-purpose water that provide financial benefits to the mining operation and contribute to better stewardship of water in the catchment.

In many cases, mining operations are located in more remote catchments, where the conditions do not suit the successful operation of water markets. Less than almost fully allocated catchments have less competition for the water, and allocations are more likely to be managed through licensing. Nevertheless, mining operations need to be aware of more localised impacts on other users, such as the effects of groundwater drawdown or the flow-on impacts of discharges of surplus water to watercourses.

Where surplus water is generated through activities such as dewatering to access mineral resources below the watertable, a good understanding of the needs of other users may identify ways in which surplus water can be provided to supplement existing water supply requirements of other users, meet the needs of new users, or be put to other beneficial uses.

Case study: Beneficial use of surplus water at Rio Tinto's Marandoo mine

The Marandoo iron ore mine is about 45 km east of Tom Price, adjacent to Karijini National Park in the Pilbara region of Western Australia. Rio Tinto recognised that the mine's 2013 expansion below the watertable would require the company to responsibly manage the discharge of surplus water in this sensitive ephemeral environment. The solution responds to catchment-scale environmental drivers and involves water management that extends beyond the mine gate to satisfy opportunities for beneficial uses in the wider catchment.

Rio Tinto developed an innovative integrated surplus water management scheme that enables the mine plan to be achieved and provides a number of beneficial uses for the high-quality surplus water. The scheme uses the water for supply to the Marandoo mine operations and accommodation village and Tom Price town and mine.

Rio Tinto has approval for limited contingency discharges to a nearby creek, and it has been proposed to reinject into the aquifer accessed by the Southern Fortescue borefield.

An environmental benefit of substituting supply to Tom Price town and mine is that it enables the existing water supply aquifer to recover naturally following 40 years of continuous use.

The Hamersley Agriculture Project uses the surplus water to grow Rhodes grass and oats on Rio Tinto's nearby Hamersley Station under a pivot irrigation system. The harvested grass provides hay fodder for cattle. The project produces economic benefits by increasing the viability of Rio Tinto's pastoral operations, as well as other properties in the region, through increasing regional fodder production and helping to drought-proof the industry. It also demonstrates the potential for economic diversity and regional development in a region that is heavily reliant on mining.

Environmental benefits of Hamersley Agriculture Project include avoiding the need to import feed from other regions; reducing the costs, greenhouse gas emissions and other environmental impacts of long-haul transport of fodder; and reducing grazing pressure on sensitive rangelands areas to improve the biodiversity and overall health of those areas.

Rio Tinto worked closely with regulators and other agencies to research the viability of using surplus mine water for irrigated agriculture and for drinking water. The project had unique regulatory and approvals challenges because it involved multiple government portfolios.

This innovative integrated surplus water management scheme has demonstrated the ability to use the surplus water from Marandoo mine in ways that add value to and manage the water resource in an environmentally sensitive location.

Rio Tinto's Hamersley Agricultural Project, using surplus water from mine dewatering.

Mining operations both affect other stakeholders or assets and are affected by other users' water management practices. Flow-on effects can increase capital costs (additional pumping, more bores, deeper bores) and in more extreme cases may disrupt mine plan and development schedules and their equivalents in other industries.

Impacts can also affect the quality of the water being used or discharged and therefore may require treatment, or they may affect the mining operation's ability to comply with approvals conditions and may have reputational impacts. Therefore, understanding the needs of other water users in a dynamic catchment becomes a critical risk that needs to be considered early in planning and mine development, through the operational phase, to mine closure.

Impacts from water management can also accumulate through the catchment and over time. Such cumulative effects are rarely considered in terms of impacts on economic assets. While cumulative impacts on environmental assets have been the focus of increasing regulatory attention, mining operations also need to consider how those impacts might affect other mines and other users, as well as their own operations.

5.3.2 Traditional owners

Cultural heritage places are integral to Indigenous communities' connection with their traditional lands. Therefore, a successful relationship between a mining company and an Indigenous community will include recognition and respect for the community's cultural heritage. Water and its flow through the landscape are a critical element of the concept of 'country' for traditional owners. The attachment of cultural and spiritual importance to water defines an important part of their custodial responsibilities for country.

Roles, relationships, beliefs and values involving water within the landscape often vary from catchment to catchment. Mining operations need to consider appropriate means of engagement on water management that recognise and acknowledge the nature of that connection.

In many cases, 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.[13] Such arrangements can be wide ranging and often need to be locally sensitive because of the local traditional importance of the issues. For water, arrangements often address the protection of watercourses or water bodies of cultural significance or the ecosystems that depend on them.

This may be reflected in formal relationships, such as Indigenous land use agreements. Some mining operations have also sought to improve their understanding of the cultural and spiritual connection of local Indigenous people to water by commissioning studies that can inform engagement and decision-making on issues of importance.[14]

For more information on cultural heritage, see the *Working with indigenous communities* leading practice handbook (DIIS 2016).

5.3.3 Communities

Access to sufficient quantities of clean water is a fundamental human right. The communities in which the industry operates, or upon which it has impacts, expect and demand that they be involved in decisions about the allocation of water resources and that industry uses water efficiently and does not negatively affect water quality. Traditionally, community and other stakeholder consultation has been undertaken during the environmental assessment and project approval stage, but engagement with local catchment management authorities and other stakeholders should also be sought during the development and review of catchment water sharing plans.

The cultural and environmental values of water can be significant drivers for regulatory and social expectations about what constitutes responsible water stewardship. Sites may have opportunities to contribute positively by working towards the maintenance of values, by actively engaging in catchment planning, and through effective engagement with the community.

13 Native title and the Native Title Act are discussed in Section 2.3.

14 For an example of developing an understanding of the spiritual values of water in the Pilbara, see Barber and Jackson (2011).

Community consultation and engagement techniques are discussed in the *Community engagement and development* leading practice handbook (DIIS 2016). Given the sensitivity of water for livelihoods, the environment and cultural support, a great deal of community engagement is likely to be required on water-related issues.

Before, during and after operations, the mining operator needs to understand the community environment: how water is used, who uses it, the seasonality of use and current and future community demands. Ongoing dialogue helps communities understand the mine's water needs and helps the industry to understand community expectations when making business decisions involving water use.

In many situations, mines provide water to community members. These range from the supply of water for stock and domestic uses to the formal supply of larger volumes for irrigation through infrastructure designed, constructed and managed by the mining company. For example, the BMA–Bingegang pipeline in Central Queensland supplies water to many stock and domestic users along its path of several hundred kilometres. Newcrest's Cadia Valley operation in New South Wales manages onsite raw water storages to ensure that downstream flow targets to supply agricultural needs are met. Water supply can also be part of agreements associated with dewatering through 'make good' agreements connected to changes in hydrological conditions caused by the mine.

Some mining companies are involved in water provision to towns and communities as water utility operators. For example, Rio Tinto Iron Ore is a licensed water service provider to the Pilbara towns of Dampier, Tom Price, Paraburdoo and Pannawonica, as well as a bulk water supplier to the Water Corporation for the West Pilbara Water Supply Scheme, which sources the water from Rio Tinto's Bungaroo borefield. Involvement in these services has its origins in mining being a pioneer development in the region, with certain rights and obligations in this area enshrined in various agreements with the Western Australian Government.

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 the community throughout the mine's life. Because impacts on water quality and hydrological systems are key considerations of closure planning and implementation, project proponents should endeavour to discuss and seek community endorsement for water-related mine closure objectives. They should also consider opportunities for the use of water by the community following closure, such as the use of open pits for aquaculture or firefighting water supply or the use of borefields for agriculture. This will minimise long-term problems with communities caused by unrealised expectations after closure.

Case study: Fitzroy Partnership for River Health—collaborating on catchment water management

The Fitzroy Basin is the largest river catchment flowing to the iconic World Heritage-listed Great Barrier Reef lagoon. The basin also hosts many of Queensland's coalmines, an expanding coal seam gas industry and extensive grazing and farming industries. The health of its waterways is a critical issue, and strategies are needed to monitor and protect water quality in the catchment from the cumulative impacts of agricultural run-off and industries' water releases. Concerns about water quality provided the catalyst for the adoption of a collaborative approach to waterway management through the creation of the Fitzroy Partnership for River Health in 2012.

The partnership brings together 25 partners who represent the basin's major sectors, uniting with a vision to provide a more complete picture of river health. The partnership has used a unique approach of pooling existing data collected by its mining industry and government partners. This dataset now contains more than 1.6 million sample results from over 200 sites. The coalmines, in particular, operate extensive networks of automated flow and water-quality monitoring stations. The data from the networks, when collated and analysed in a joint manner, provides invaluable information about water quality in the catchment.

A key deliverable from this collective action is the publication of annual aquatic ecosystem health report cards, which grade the overall water quality in the catchment and provide detailed scientific information. That information can be used by stakeholders interested in the data and analysis that yielded the report-card grade. An innovative data management and web visualisation platform was developed to support this activity.

The partnership has provided opportunities for mining and other industry players to build productive relationships with other stakeholders in the catchment. It has also helped share the burden of extensive field monitoring, as data is gathered from a range of sources. This collaborative approach by industry and government is an important step in providing a clearer picture of water quality in the Fitzroy Basin.

Members of the Fitzroy River Partnership (http://riverhealth.org.au).

5.3.4 The water–energy–food nexus

Mining companies need to recognise the broader linkages and tensions between their use of water and the use of water by other sectors, such as energy and food production, and to factor those interactions into assessments of risks for water management in the catchment. The water–energy–food nexus concept recognises the close linkages between the sectors and that actions in one area can often have significant impacts on the others (Hoff 2011). The linkages among water, energy and food are brought more closely into focus as demand for all three increases, but particularly as competition for water increases.

The concept of the water–energy–food nexus is relatively new. Nevertheless, the broad implications for the way a mining company manages water are the need to be aware of the linkages and how they may manifest and cause impacts in the catchment. The concept extends the notion of water stewardship to include wider effects on energy and food. Tensions and interactions between the three sectors have already been apparent in the recent development of the coal seam gas industry in Australia, and that experience highlights the need to factor these interactions into assessments of risks and opportunities for water management in the catchment setting.

Consideration of these linkages by mining companies will also encourage a more appropriate valuation of water, which can inform decisions that mine operators make about accessing water sources that are fit for purpose, ensuring appropriate levels of investment in water efficiency and water recycling, and considering appropriate and responsible opportunities for the disposal of water that is surplus

6.0 CATCHMENT-BASED WATER MANAGEMENT APPROACH

Key messages

- A catchment-based water management approach requires a fundamental technical knowledge of the regional surface water and groundwater context, water users and key values.
- All components of the hydrological water cycle, including surface water and groundwater resources, need to be considered for responsible water management.
- Defining the region or catchment is an important initial step to ensure that the full water-balance dimensions and water-dependent assets and values are identified and quantified.
- Australia's national goal for the provision of water to the environment is 'to sustain and where necessary restore ecological processes and biodiversity of water-dependent ecosystems'.
- Characterising the catchment hydrology generally requires data supported by monitoring facilities, including climate, surface water flow and groundwater monitoring.
- Climate change and climate variability (for example, reductions in precipitation and more severe floods) will be different in different parts of Australia. It is important to consider future conditions in predictions of water availability and in assessments of impacts.
- Water-dependent environmental assets, culturally significant sites and third-party water demands need to be identified, and the value of the assets needs to be agreed upon by the broader catchment stakeholders and regulators.
- Regional-scale technical uncertainty in mining areas can be considerable, so managing water resources requires an appreciation of margins of error and temporal and spatial variability, whether due to climatic and seasonal variance or local geological factors.

A catchment-based water management approach requires a fundamental technical knowledge of the regional surface water and groundwater context, the water users and the key values. In particular, hydrological controls and conditions are important inputs to the water balance that underpins many underlying cumulative, community and environmental issues.[15]

Shifting into a regional context for water management without investing in fundamental technical knowledge will potentially expose the mining company to greater risks, ultimately resulting in poorly informed investment decisions and commitments. Therefore, establishing an understanding of the catchment's surface water and groundwater characteristics and controls and the water balance, storages and conveyances is an important initial component of a catchment-based approach.

15 More detailed discussion of the interaction of the operational mine water system and the catchment is in sections 8, 9 and 10.

A comprehensive technical knowledge of the surface water and groundwater characteristics and controls is normally required, as a catchment-based approach typically requires the operator to monitor and assess conditions beyond the mine lease or tenure. This requires:

- larger datasets and more monitoring facilities, some of which may be shared with other miners, farmers and other industries
- datasets that are designed to provide data on different temporal and spatial scales to address internal and external stakeholder issues
- an improved knowledge of the dependencies, functions and resilience of water receptors, some of which are located off the tenure and within neighbouring catchments
- regional predictive tools that consider appropriate scale and technical uncertainty
- a fundamental understanding of existing utilities and infrastructure capacities and limitations in the catchment
- active water management techniques in areas outside the mine gate, some of which may be shared with other miners, to prevent or mitigate impacts.

The requirements to operate and establish monitoring outside the immediate mine lease (or to share data in a timely manner) can introduce some difficulty and logistical challenges, particularly when key knowledge is needed about other mines, industries, sensitive receptors or landholders, or technical gaps occur in their vicinity. Land access, data-sharing issues and overall water management agreements evolve over timeframes that require long-term commitment and investment.

6.1 Establishing the appropriate catchment scale

Defining the region of interest or the catchment domain is an important initial step that can need careful consideration to ensure that the full water-balance dimensions and water-dependent assets and values are identified and quantified. This requires a review of the surface water catchment, the hydrogeology (including the potential for interconnections between aquifers and with surface water), and any water transfer that occurs as part of a water network or that can occur naturally during different seasons. The catchment domain may vary seasonally and as new operations and industries emerge and water is possibly traded or shared.

Defining the surface water hydrological catchment is a reasonable starting point for defining the catchment domain, followed by an overlay of groundwater conditions and likely interconnections with neighbouring catchments. In large surface water catchments or where aquifers are extensive, catchment domain definition may need to consider the likely area of effect or change that may result from a mining activity or cumulative effects resulting from multiple operations. Changes to the catchment domain are likely to occur as catchment knowledge is further developed, but regular modification of the catchment boundary should be avoided because it would make maintaining management consistency difficult.

Some up-front analysis and predictive modelling can be used to support the definition of the catchment domain, including for surface water and groundwater. It is important to develop a conceptual hydrological model of groundwater on the local and regional scales that considers recharge and discharge, interactions between aquifer units, and interactions with surface water, groundwater-dependent ecosystems and other water users. The development of numerical or analytical models to test the conceptual model can follow. Monitoring programs can then be refined based on the outcomes of conceptual and analytical or numerical modelling.

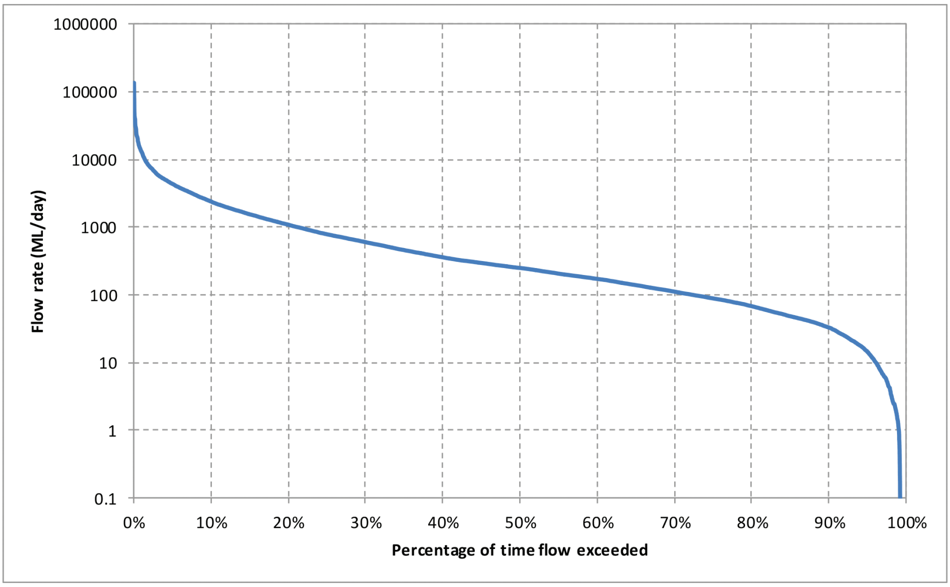
6.2 Developing a hydrological baseline and an understanding of existing utilities

Characterising the catchment hydrology generally requires data supported by monitoring facilities that typically monitor climate, surface water flow, and groundwater and surface water level and quality. Targeted technical assessments may also be needed to characterise surface water and groundwater conditions at key receptors or water infrastructure.[16]

From an environmental perspective, surface water flow volumes, rates and quality and groundwater levels, flow direction, flow rates and water quality are all important information sets used to understand the natural variance and hydrological conditions within different parts of the catchment or subcatchment and the impact that the mine is likely to have on them.

A typical feature of creeks and rivers in Australia is extreme flow variability (Figure 4). The mean annual average flow of a river can be 1,000 ML/day, with greater flows occurring less than 20% of the time. The same river will essentially cease to flow for 5% of the time. As illustrated in Figure 4, taking only the average annual flow into account will not provide a high-level understanding of the system.

Figure 4: Flow duration curve of a river in inland New South Wales



Note: Data from NSW Office of Water gauging station 412147 on the Macquarie River at Bruinbun.

16 See sections 8.1.3 and 8.2.3 for details of baseline assessments.

Mining operations occur in a wide range of environments across Australia, including wet and dry regions with strong or weak seasonal variation. Mining needs a reliable and consistent water supply, which in highly seasonal climatic conditions could require additional water licences, entitlements, bores or storages. This requires operators to recognise that variability in environmental conditions and to plan for and manage it during all phases of the operation. The key to managing environmental water requirements is to understand the temporal dynamics of the catchment.

An understanding of existing water utilities is also necessary to understand the water balance within the catchment. Water infrastructure capacity, condition and reliability; water storage; limitations on distribution; and changing seasonal requirements are some of the important baseline elements to map. Any assessment that considers the capacity and reliability of water infrastructure should include consideration of adequate planning for the impact of climate change, such as flooding.

The extent of new monitoring requirements and networks is different for each catchment and largely depends on the catchment's hydrological complexity and water challenges, the level of certainty that is appropriate to deliver management solutions, and the historical information available. Catchment monitoring is an essential component of simulating and predicting water flow through the landscape and is the basis for calibrating models. Where monitoring locations are further from the operation, the installation of telemetry or loggers can reduce logistical requirements.[17]

6.3 Identifying the key water features and assets

A robust understanding of the hydrological functions that support the key water features and assets will ensure that appropriate and fit-for-purpose management conditions, triggers, thresholds and targets are established. In addition, establishing the proportion of potential impact or change effected on a receptor by a mine or by third parties also contributes to an appropriate level of understanding. Ecological surveys and hydrological assessments, together with cultural, community and regulatory engagement, are important activities that are necessary to define the functional value of the assets. Some studies and investigations may need to be completed in coordination with other miners and the local community.

Not all catchment-based assessments are focused on identifying and managing the potential for environmental or third-party water impacts. Such assessments are also made to identify and establish possible synergies, contingencies and water supply or trading opportunities. The key water features and assets that need to be considered in a catchment may also include natural water resources or modified or recycled water resources available from other miners, utilities and community projects. Establishing those opportunities and assessing the costs and designs to move water between supply and demand points are keys to successful early planning.

17 See sections 8.1 and 8.2 for more operational detail on monitoring and data collection.

6.4 Evaluating and predicting hydrological and water-balance change

The assessment methods and techniques used to evaluate hydrological change on the catchment scale are typically similar to the tools used at a mine site (for example, conceptual hydrological models on local site and catchment scales to support analytical and numerical modelling). The main differences are the scale, the extent of uncertainty and the need to potentially share the model with other miners. This can introduce governance and data-sharing complexities, some of which may require the control of information by an independent third party or an appropriate regulator.

Assessment and predictive tools can be used to simulate surface water flow regimes, rates and directions of groundwater flow, and sustainable abstraction limits. Predictive capabilities of the models are then used to define the various water balance scenarios and the range of impact outcomes that can result from the individual and cumulative effects of the mine. Proponents need to recognise that the technical uncertainty in data availability and quality can result in limitations to the outputs. Catchment-scale models and the interpretation of the results of those models must be fit for purpose, and multiple scenarios usually need to be considered in the analysis to support effective and appropriate decision-making. Conceptual hydrogeological models are required to identify areas of uncertainty and focus, after which analytical and numerical models can further clarify uncertainties and inform the choice of monitoring locations and frequency.

Catchment-scale assessment tools can be used to simulate various management techniques to mitigate or avoid impacts. The application of such tools for this purpose needs to recognise the limitations of data and outputs at a distant receptor, particularly if limited data exists on the interaction of the management action of concern and the relevant receptor.

6.5 Technical basis for catchment-scale water management

Active water management solutions to prevent or mitigate off-tenure or catchment-scale impacts, and even to share or trade water resources, are underpinned by catchment-scale technical knowledge. Delivering water to a third party, maintaining the artificial discharge of a spring or establishing a functional water trading system all require a fundamental understanding of the water resource and the key components of environmental, scientific and engineering uncertainty. Some of the solutions will come through collaboration with other miners and third parties, investment in research and development, and cooperation on operating plans.

Catchment-scale technical uncertainty in mining areas can be considerable, and managing water resources at this scale requires an appreciation of margins for error and temporal and spatial variability, whether due to climatic and seasonal variance or local geological controls. In the absence of long-term historical datasets and the presence of limited predictive capabilities, conservative management solutions with precautionary thresholds may need to be considered initially. Importantly, management controls need to reflect this range of uncertainty and possible impact outcomes. With improvements of data and knowledge through adaptive water management (Section 7.2), the precautionary management approach can transition to more specific thresholds and better defined management measures.

For example, management triggers or thresholds to prevent impacts on an aquatic ecosystem from the discharge of surplus mine water during a wet season may need to be initially set within the natural variance or range in the values of key hydrological parameters, such as nutrients, pH and salinity. Those values are typically developed through monitoring over a number of years and seasonal cycles. With greater technical knowledge generated from scientific assessments, the management trigger may shift to more specific ecologically based thresholds that consider species or community adaptability and resilience to change.

The adaptive management approach outlined in Section 7 applies well to catchment-scale water management, particularly where limited or imperfect data or gaps in hydrological knowledge exist. Knowledge improvement, supported by adequate monitoring and analysis, typically drives less conservative outcomes and provides transparency on risk and a basis for greater confidence among local communities and other water users.

Case study: Catchment-scale water management at BHP Billiton Iron Ore

BHP Billiton operates iron ore mines in the Pilbara region of Western Australia that are accessing ore from below the watertable. The company recognises the need to manage drawdown of the aquifers and discharges of the fresh surplus water to reduce long-term impacts to environmental, cultural and community values, while achieving production targets and enabling future development. It has achieved those aims through the implementation of three catchment-scale adaptive management plans covering an area of 25,000 km^2 in the upper Fortescue River catchment.

The plans identified environmental, cultural and water resource values (established as receptors), consolidated the technical knowledge about the water resource and water-dependent ecosystems, set hydrological and ecological management thresholds for each receptor, and then introduced management techniques to offset impacts and minimise groundwater drawdown.

The plans are supported by a regional hydrological monitoring network of up to 250 monitoring facilities located outside the mine gate. A number of techniques (for example, managed aquifer recharge) have been successfully tested to return surplus fresh water (over 60 ML/day) from 14 below-watertable pits to the regional aquifer.

Ophthalmia Dam in the upper Fortescue River near the town of Newman in the Pilbara (left) and one of BHP Billiton's groundwater injection wells (right).

Effective catchment-scale water management was due to:

- the risk-based water strategy being informed by corporate objectives and having a long-term business case
- the water strategy being underpinned by the three catchment-scale adaptive management plans
- governance and corporate reporting targets that managed the range of hydrological change to within acceptable outcomes.

Success was measured by three targets, including two corporate reporting targets:

- the percentage of the total surplus mine dewatering volume that was returned to the aquifer to minimise impacts and reduce the area of influence—50% target, 70% stretch
- installation and monitoring of the network of 250 monitoring facilities (groundwater, surface water and weather) outside the mine gate to monitor baseline conditions, provide early warning of change and identify potential impacts
- compliance with water licence conditions to ensure that stipulated volumes were not exceeded.

Benefits are being realised through streamlined legislative commitments, production flexibility and overall water stewardship outcomes. In addition:

- Impacts to culturally significant springs and creeks are prevented by returning surplus water to the aquifer. This surplus management approach is consistent with traditional owners' expectations.
- Impacts to seven key groundwater-dependent ecosystems and the broader water resource are minimised through targeted managed aquifer recharge.
- Access to below-watertable ore is not constrained by the challenges of surplus water, and production targets continue to be achieved.

6.6 Climate change and climate variability

Climate change and climate variability impacts will differ across the various regions of Australia. Some regions, such as Western Australia's south-west region, have experienced a widely acknowledged significant reduction in precipitation over the past decade, while others, such as northern Australia, are experiencing severe weather. The impacts are uneven and in many cases difficult to predict. Nevertheless, these effects have the potential to influence the hydrology of certain catchments and to contribute to environmental stress and change.

In many areas of Australia, interannual variability in climatic conditions results in cycles of wet and dry periods that span a number of years because of systems such as El Niño and La Niña. These processes are associated with a sustained period (many months) of warming (El Niño) or cooling (La Niña) and can occur over timescales of one to eight years. Mines managing for such periods require both flood- and drought-tolerant water management plans.

Over time, individual operations may experience climate change and climate variability through increasing operational risks, such as more intense floods that result in physical damage to water management infrastructure or in impacts on production from the flooding of mine pits. Operations may also experience regulatory risk through the management of floodwater discharge and release and the attendant environmental impacts.

Reductions in the availability of water due to climate change may affect an operation through increasing competition for water if the mine is in a catchment with nearly full or full allocation. Conversely, flooding of operations and damage to infrastructure may occur due to more severe storms. Most water users have the same requirements at the same time. Most users in a region have excess water at the same time or require increased withdrawal at the same time, so the cumulative effects in the region are exacerbated at times of stress. This may result in the placing of caps on the total volume of water available for consumptive purposes or for mine use. Climate change and climate variability may also affect the volume of water available for environmental use or may have other environmental impacts, for example through changes to mean temperatures.

Where mining operations are being monitored and measured by their impacts on high-value environmental assets, it is important to ensure that performance against triggers, targets, limits and thresholds includes some allowance for impacts that are exogenous to mine-related activity, such as climate change and variability. Attributing impacts due to climate change can be a difficult task, as they can occur over a long period and are not easy to measure. For example, in ephemeral streams, which can exhibit significant natural variation in water flows that may enable a level of tolerance and resilience in water-dependent receptors, the effects of climate change and climate variation might be masked if they accumulate slowly. Mining companies need to monitor research on this issue and use it to inform decisions and actions related to regulatory issues to ensure that regulators appreciate that not all impacts can be attributed to water users.

6.7 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 make critical contributions to river health, economic development and poverty alleviation.

As a result of the Council of Australian Governments review of water resource policy in Australia (COAG 1994), a set of national principles for the provision of water for ecosystems was developed. It 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' (ANZECC–ARMCANZ 1996). In support of those principles, the eWater CRC developed the River Analysis Package, which is normally used in conjunction with hydrological models.[18]

The management of water on a mine site can alter key flow characteristics of downstream watercourses by:

- causing extended or elevated base flows due to relatively constant discharges, such as from mill operations or dewatering
- time shifting rainfall run-off and attenuating flood flow peaks, such as by capturing of site run-off and treating it in retention ponds
- reducing site run-off, for example by using a zero-release strategy or enhancing onsite evaporative losses of water from potentially contaminated areas
- increasing flood flow peaks and reducing base flows by reducing infiltration or increasing run-off rates, resulting from the removal of natural vegetation and soil covers of areas or from the compaction of soils and subsoils
- disrupting relationships between surface water and groundwater systems
- diverting of water from one catchment to another
- converting temporary waters to perennial waters or vice versa.

18 River Analysis Package, http://www.toolkit.net.au/Tools/RAP.

Leading practice management of the flow impacts of water discharges from a mine site should be compatible with the relevant legislative frameworks and take into account the environmental flow objectives that have been determined for the affected catchment.

For example, the conversion of an ephemeral stream to a perennial stream as a result of ongoing discharges of mine water (for example, from dewatering operations) will disrupt the natural ecological processes that depend on seasonal variations in flow and 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). Establishing 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), the riparian vegetation needing year-round water will die, resulting in destabilisation of the banks and increased erosion. In this circumstance, rehabilitation of the stream banks may be required.

Groundwater-dependent ecosystems can be damaged by changes in flow and water quality (see Section 6.8 for an example involving species that spend part of their lives underground). Changes to flow regimes can 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 will depend on the implications for the catchment and, in particular, for any sensitive, rare, threatened or endangered species or communities that rely on the natural water cycle.

These risks need to be considered and managed. In some circumstances, changes in environmental flows might not always have the same long-term impacts. The long-term effects of such changes can be tempered by the resilience of the affected ecological systems. For example, a longitudinal study of the Robe River in the Pilbara region of Western Australia found that the effect of continued discharges of surplus mine water to this particular ephemeral river were not detrimental to freshwater biodiversity, although permanent flows may increase the incidence of introduced flora (Dobbs & Davies 2009). Such studies are important to maintain a regime of ongoing monitoring and research on the impacts of changes to hydrological regimes resulting from mining activities and to provide a level of information to regulators and other key stakeholders who have an interest in the catchment-level impacts of water management.

Leading practice management of the flow impacts of water discharges from a mine site also considers the broader implications for the receiving catchment, even if compliance is achieved at a point specified in the mine's operating authorisation. For example, the passage of aquatic organisms (such as fish) through watercourses can be inhibited or entirely prevented by chemical barriers caused by poor water quality. Considerations for physical barriers are equally relevant, 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.

6.8 Stygofauna: an example of groundwater-dependent species

Stygofauna are an example of groundwater-dependent species that can be impacted through mining. Stygofauna are subterranean fauna (predominantly crustaceans, worms, snails, insects, and other invertebrates) that depend for at least part of their life cycle on groundwater. Groundwater communities typically comprise species that are found only in a very small area (called 'short-range endemism'); and in some cases, entire species can be vulnerable to changes in groundwater level and flow.

Awareness has been emerging of the potential for dewatering associated with below water mining activities, for example, in Western Australian iron ore mines, to impact stygofauna through impacts on groundwater. However, uncertainty about species distribution and diversity, the extent of endemism, and species resilience has resulted in uncertainty about impacts. This has led to requirements to consider impacts on stygofauna as part of the environmental assessment process for new mines and other developments affecting groundwater and even to specific guidelines for acceptable approaches to assessment (WA EPA 2013). The underground habitat of stygofauna leads to highly specialised adaptations that greatly increase the likelihood of short-range endemism (Environment Protection Authority 2013) and therefore increased uncertainty about impacts on endemic species and biodiversity.

The protection and conservation of subterranean fauna (stygofauna and troglofauna) is enabled under both state environmental legislation and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and it is essential that any project likely to have impacts on groundwater consider statutory and regulatory assessment obligations as part of the standard planning and approvals processes.

Adequate surveys are critical to understanding the species that may be present and will help to minimise approval conditions, approval delays, and monitoring and compliance costs. However, assessment of subterranean fauna is often complex due to the limited knowledge of species distributions and habitat requirements and to the difficulties of conducting surveys.

PART IV: OPERATIONAL WATER MANAGEMENT

Part IV outlines the elements to be considered in achieving leading practice operational water management. Section 7 introduces the need to set clear objectives for water management that align with the level of water risk that the operation faces. A strong business case for alternative water solutions based on risk and risk tolerance will help the company understand the costs and benefits of various options.

Understanding the biophysical catchment context for the mine (Section 8), developing and operating the mine (Section 9) and optimising the mine's water system (Section 10) will involve varying degrees of complexity, depending on the nature of the operation. The selection of leading practice approaches will depend on a cost–benefit analysis that takes into account the magnitude of the risks and the level of required mitigation.

7.0 WATER PLANNING AND ADAPTIVE MANAGEMENT

Key messages

- Water management for mining operations requires an appropriate lead time for planning and should be risk and opportunity based.
- Water management should be adaptive and should adopt practical and feasible water management techniques that incorporate key learnings.
- A good understanding of risk and risk tolerance is needed to determine the costs and benefits of different options.
- Water risks and opportunities can be managed by establishing a longer term water planning horizon that is informed by existing operational considerations and prepares the operation for a range of possible mine development scenarios and water-balance outcomes.
- Setting formally agreed operational and stewardship objectives and processes, and implementing monitoring and reporting systems for them, allows effective water risk management and productivity improvements.
- Site-specific strategic water plans are essential for setting water management targets and expectations and outlining accountabilities and performance measures.

7.1 Water management planning

Leading practice water stewardship requires good planning and preparation and the selection of the right tools and applications to enable water management to be a driver of productivity.

7.1.1 Planning and preparation timeframes

Water is both an enabler and a constraint for mining companies. As an enabler, it is an essential requirement for mineral processing and dust suppression. As a constraint, poor water management can lead to ineffective diversions, production impacts from pumping or treatment problems, environmental impacts, and community concern, and can require considerable management time and expense to rectify. The management effort that water receives is different for each company and operation. Individual companies need to establish clear water management objectives, principles and measures that effectively span mid- to long-term planning and operational horizons, address their risk profile, consider the operational complexity and, importantly, consider costs and benefits.

Although an ad hoc approach to water management can be effective for immediate water issues and crises, a lack of clear objectives, principles and measures is more likely to increase operational costs and reduce flexibility in the mid-term and potentially lead to early, forced, unplanned closure, loss of reputation and long-term impacts. Ad hoc water management can also become a focal point for grievances in communities whose members wish to express a broader discontent with the mining company. The extent to which integrated water planning and management are required varies depending upon a range of factors such as the scale and size of the operation, the operation's reliance on a finite water resource, the cost of water activities, and, importantly, the operation's vulnerability to environmental, catchment-scale and social issues.

Although many mines experience periods of water control, it is commonly accepted that water issues become a material risk at some point for most operations. Most operations will benefit from providing an appropriate lead time to consider the multiple water risks, interfaces and governance structures that apply to the planning of operational design and improvement processes.

Timeframes for water management planning and implementation do not always align with mine development or mine planning schedules; therefore, planning horizons and operational approaches need to be adaptive and flexible enough to address variable and changing water demands, discharge volumes or dewatering requirements. If an ad hoc approach is adopted without setting a clear strategic objective, the impacts can be costly and inconsistent with leading practice water stewardship.

For example, increased mine production can be developed within 1–3 years, particularly for existing operations, while a supporting water supply for the equivalent growth from either a desalination plant or a borefield may require up to five years of assessments, approvals and development, thus placing the activity on a project-critical path. Having completed a supply option analysis and plan in a strategic context will enable the faster delivery of possible future mining options and, at the same time, will serve as a contingency for an existing supply. An additional example concerns post-closure timeframes and the long lag-time for potential groundwater responses to be manifested.

If broad water management alternatives are not in place at the right time and mapped to various future mine planning options, then any deviation from the long-term mine plans and operational schedules may have production impacts. Capital and operating costs need early investment to mitigate such impacts. Alternatively, the company needs to accept the higher risk position for potential production and stewardship impacts and the resulting costs.

7.1.2 Technical tools and applications

Technical tools and methods developed for the broader water industry are typically applicable and transferable to most mining situations and operations, including numerical and analytical models, water databases, monitoring instruments and reporting programs. Those tools and processes, particularly water accounting (see Section 11.2), can be used to provide numerical capacity to address the complex interactions between observed and predicted water outcomes to support an alternative mine development case or operational scenario.

This analytical approach can provide the basis for communicating technical uncertainty and water risks (such as a probabilistic output), particularly when imperfect information is available for decision-making. A well-maintained (calibrated and fit-for-purpose) and robust water balance that spans short- and long-term time horizons and provides inputs to a water account is an essential tool for a leading practice operation.

7.1.3 Water management planning as a productivity driver

Timely water planning and execution with robust investment decision points enables both production and stewardship opportunities to be achieved and can facilitate faster project delivery.

A strong business case for alternative water solutions based on risk and risk tolerance will help the company understand the costs and benefits of various options. The design of surface water management facilities and infrastructure, such as pit diversion drains and in-pit pumping configurations, is inherently probabilistic, and the designs will reflect the risk tolerance of a specific average recurrence interval (ARI) rainfall event. For example, a short-term (2–5 year), open-cut mining operation may choose a wet weather management design that reflects the short period of operations (say, a 1 in 10-year ARI event) and, in doing so, would carry the probability of a high-rainfall event occurring and reducing production. Although capital and operating expenditure can be reduced by this design, the costs of potential impacts should be highlighted and a conscious business decision made to carry a higher risk tolerance. Alternatively, a less frequent ARI event may be selected, which would limit the risk but increase the capital and operational expense.

The operational and capital expenditure for water infrastructure can be substantial. Delayed or poorly designed water investment can be a primary cause of future production impacts or increased operational costs. The design and operation of pumping equipment require continual review, as the capital costs of pumps can be around 5% of the life cycle costs; by far the largest proportion of pumping costs are associated with energy use (Rea & Monaghan 2009). As pumping heads and volumes change over time, the operational energy costs may be significantly reduced by reviewing pump specifications and hydraulic performance and substituting more appropriate and fit-for-purpose pumps.

The deferral of an investment in water management and infrastructure requires careful consideration. Any business case for significant water management should clearly identify the direct and indirect costs as well as the mid- and long-term benefits that could be gained by the investment. In general, water infrastructure is ultimately used for purposes that are additional to the nominal design purpose, and a broader application should always be considered during a business case development.

Water management decision-making typically relies on a strong technical basis. An early investment in science and engineering through drilling, testing and monitoring will typically address uncertainty and realise value through fit-for-purpose designs and a reduction in the maximum foreseeable loss during operational stages. Poorly engineered water diversion designs and inaccurate groundwater supply estimates have led to increased costs for mining operations throughout Queensland coalfields in recent years, and those costs could have been controlled through better scientific research and engineering investment.

A well-developed and accurate environmental approval document or environmental impact assessment can result in timely approvals with fewer legislative conditions. Conversely, a poorly developed assessment can result in delayed approvals and ultimately affect production targets.

Strategic investment in water stewardship, supported by good science and proactive engagement, can correlate with lower long-term production costs and improved security of water supply. However, the direct benefits are not always immediate, and building the company's reputation as a good water steward requires consistent messaging, clear objectives and transparent communication. These benefits can be realised through increased environmental approval speed, sometimes with fewer monitoring and reporting requirements. Leveraging these benefits typically requires:

- robust monitoring and reporting compliance for existing conditions to build regulatory confidence
- investment in scientific knowledge about the broader catchment environments
- proactive engagement and a willingness to share data and address cumulative effects with neighbouring mining operations, communities, traditional owners and other industries.

7.2 Risk-based and adaptive water management

Mine water challenges can be managed and opportunities realised by applying a number of overarching approaches that address the risks associated with different geographies, development timeframes and operational complexities. They include:

- adopting a risk-based approach
- incorporating adaptive water management to incorporate key learnings into an improvement process
- operating to agreed objectives, strategies, plans and procedures.

7.2.1 Adopting a risk-based approach

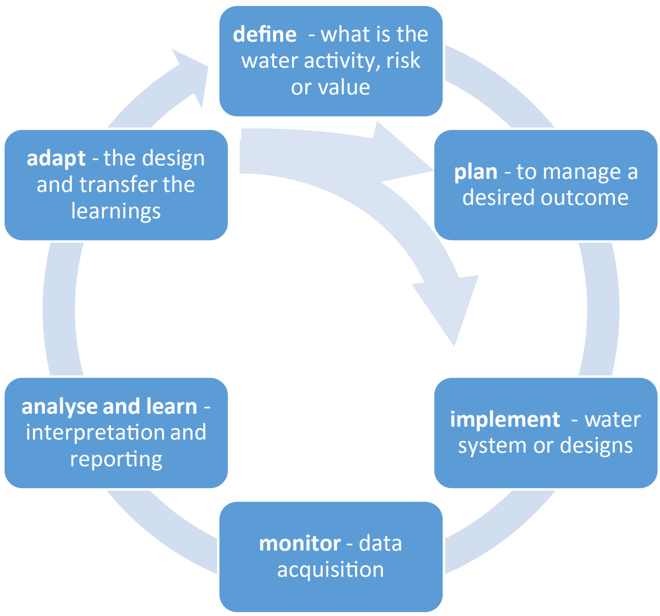
A risk-based approach can effectively identify and mitigate various and potentially interdependent water issues that can individually or collectively affect an operation or the surrounding environment. It can also prepare the business to make informed and timely decisions on a range of possible water outcomes by presenting different levels of risk likelihood and consequence, as well as the costs and timeframes associated with preventive and mitigating controls. Ideally, a well-developed risk assessment should span multiple timeframes from planning through to operations and closure, consider both mine site and regional aspects, and address water stewardship initiatives and regional or catchment considerations and corporate responsibilities that can drive some complex outcomes. Risk assessments are also effective for tactical or immediate decisions, such as determining a new or changed discharge point during a flood or evaluating a short-term climatic variance effect on water supply.

As part of a risk-based approach, the mine should continually identify and review key water-affecting considerations annually (as a minimum) and develop a technical and business basis for the risk assessment process and controls. Using existing corporate or industry standard approaches is recommended for consistency and for easier risk comparison. In the absence of a formal risk assessment process, establishing water risk categories and considerations forces non-obvious risks to be debated, such as whether to invest in short-term or long-term secure water supplies for the life of the project. This example risk has a number of interdependencies that may need separate and collective review, and the risk variables will vary over the life of the project. During the early stages, the key water risk consideration may be the delivery schedule and approval. As the operation matures, the risk profile will be likely to shift to such considerations as achieving licensing commitments, preventing infrastructure failure and managing for potential environmental impacts from acid rock drainage or stormwater run-off.

7.2.2 Adaptive water management

Adaptive water management is an iterative approach to decision-making in which key learnings and understandings are actively reviewed and incorporated into an operational mine management plan to improve management objectives and resolve challenges (Figure 5). The approach is applicable to mine water management environments owing to the considerable uncertainty that arises from technical, mine development and logistical unknowns and variances, which can occur throughout the mine's life cycle. This approach can also introduce operational capacity and flexibility to accommodate changes to mine plans or regulatory requirements.

Figure 5: Adaptive management approach, modified to address mine water management challenges and opportunities



Greater operational flexibility and better water systems can be introduced over time by planning for a range of scenarios and incorporating monitoring data and key learnings into plans and operational activities. Adaptive management does require an initial management position with sufficient information to make a sound decision, sometimes based on limited data, while setting mid- to long-term improvement objectives. In the absence of sufficient information, a precautionary water management approach can be considered where the initial designs or operating models suggest a conservative approach.

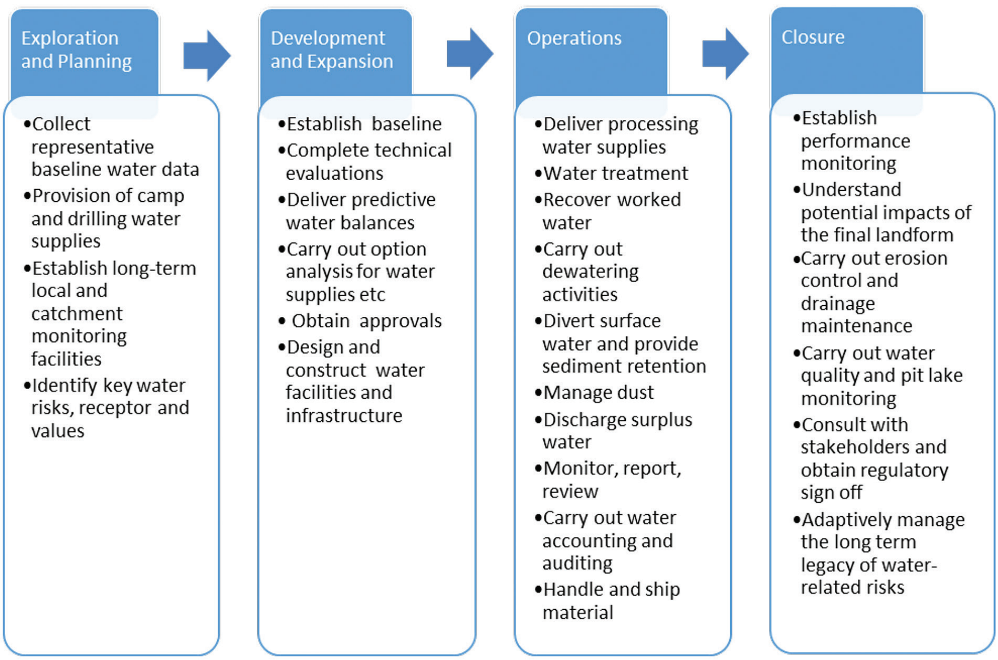
For example, early mine dewatering information may be insufficient (possibly due to imperfect science) to determine the mid-term pumping rates; thus, early stages of the integrated site water balance may need to consider a broad range of volumes and potential water qualities. As a result, a mine water supply and surplus water management plan may need to accommodate that variance. Similarly, when assessing environmental impacts, early time-series data may be unsuitable for predicting long-term trends and changes, so precautionary thresholds and triggers may need to be introduced to manage for the uncertainty of impact.

Adaptive management can be particularly powerful when coupled with risk management. The downside is that overinvestment may occur owing to the extent of uncertainty, and the design standards and capital expenditure may need to be higher than required.

7.2.3 Water strategy and operational plans

The water management activities that need consideration during different stages of mining are outlined in Figure 6.

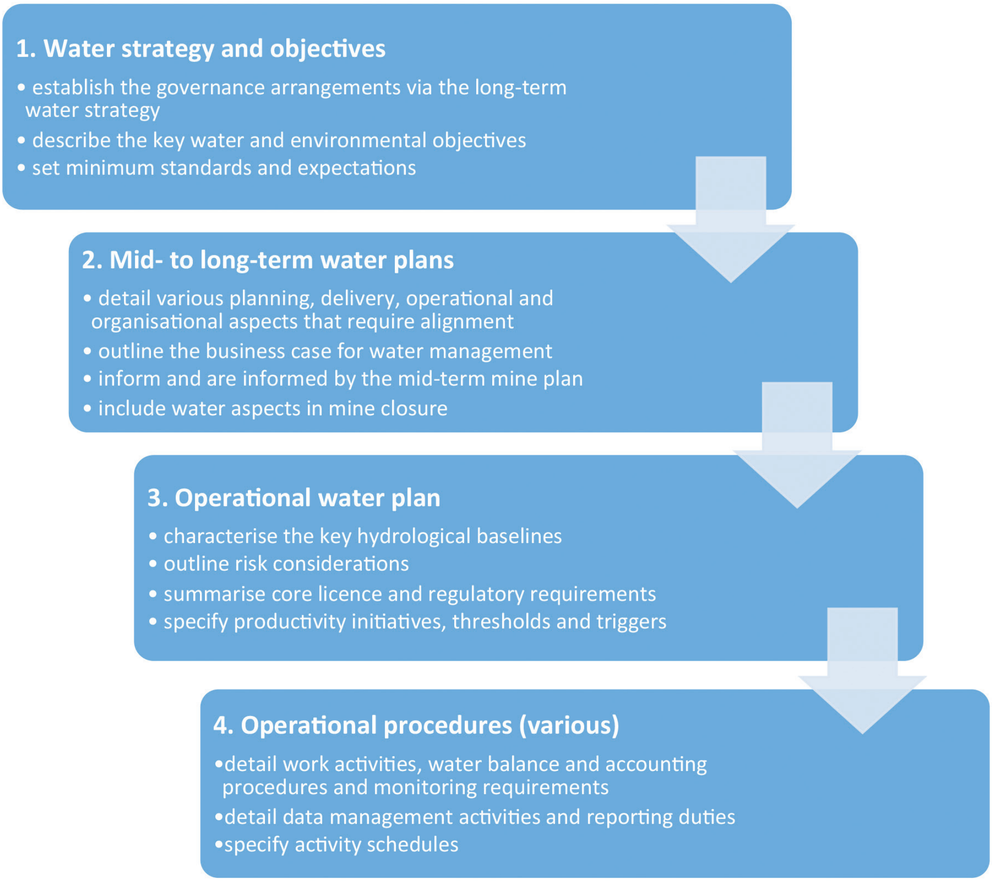
Figure 6: Water management activities at various stages of a mine's life cycle



A number of key cascading strategies, plans and procedures (shown in Figure 7) align to the stages shown in Figure 6 and can be the basis for preparing for and achieving successful water management outcomes, including:

- water strategy and objectives
- mid- to long-term water plans, including water aspects of the closure plan
- operational water plans
- operational procedures.

Figure 7: The main components of the planning and processes required for leading practice water management



Water strategy

A water strategy sets directional and overarching water stewardship objectives, summarises the key water risks, opportunities and broad organisational linkages, and outlines the fundamental planning, project delivery and operational framework to ensure that water management is considered in all phases of mine planning. The water strategy should be updated or reviewed annually or more frequently if the business need dictates.

An overarching water strategy is effective for companies with multiple operations seeking production benefits that can be achieved through a consistent and standard approach to water management. A water strategy typically addresses the water-related aspects of a company's production targets, vision and values; state and national regulation and policy; and best practice guidelines. Smaller operations may benefit from preparing a water strategy but may choose to include water-related aspects in broader planning documents that address the appropriate planning horizon, such as the mine plan or environmental plans.

Case study: Newmont Water Strategy setting direction for improved performance

Over the past five years, the mining industry has experienced significant water-related challenges due to changes in regulatory requirements, community activism, and unanticipated and unbudgeted water incidents or issues across all regions. Water access, availability and quality have become political and social platforms that have the power to delay or stop mining projects or expansions.

In 2013, Newmont developed a Global Water Strategy that was endorsed by the executive leadership and the board of directors. The strategy is based on five pillars, each with fit-for-purpose programs to drive implementation:

- Water security—taking a watershed approach
- Impact and opportunity management
- Operational excellence
- External engagement with stakeholders
- Internal engagement on water.

The implementation phase for the Global Water Strategy formally began in January 2014 with a planning workshop that brought corporate and operational water practitioners and leaders from each region to work on developing the implementation plan and key milestones for 2014 and beyond. The session facilitated regional input directly in the planning to ensure active engagement and alignment from the team. Executive leaders were involved in a number of workshop sessions, sending a strong message of leadership support for the water strategy.

The 2014 implementation plan included an engagement program, as well as regional and site workshops where the high-level Global Water Strategy was refined to reflect regional and site-specific conditions while maintaining all the elements of the strategy. Some of the major benefits that were realised and supported from an early stage were improved governance, a single point of accountability for water decisions and the creation of appropriate systems to understand the full cost of water in business planning.

The strategic site water management plans that were developed towards the end of the year included detailed roles and responsibilities, as well as action plans to address longer term risks and opportunities. For Newmont's water management, 2014 was a big year as the organisation moved from a high-level strategy to fit-for-purpose regional strategies and site-specific water plans. Work defined in the corporate and regional implementation plans, as well as in the site action plans, was expected to continue over the next three to five years.

Newmont's Boddington Mine in south-west Western Australia. The mine separates potentially contaminated water drained from the waste dumps from the raw water storage facility in the background. The water is pumped back to the plant to be used preferentially in place of raw water.

Mid-term, long-term and operational water management plans

As a minimum, an operational water management plan is fundamental to leading practice water management. The plan's size and complexity depend on the nature of the operation, hydrology, and the community and environmental sensitivity of the surrounding area. It is a summary of water use, storage and distribution and identifies all water management project issues, risks and controls associated with developing, operating and decommissioning a project. The plan is guided by the water strategy or by a mid-term water plan or mine plan and specifies how to manage and control potential adverse impacts on the local and regional water resources. The main water activities to be covered at each stage of the life cycle are summarised in Figure 6.

Although an operational water management plan is considered essential in most cases, multiple sequential water plans may be needed to ensure that the operational water management plan and proposed activities effectively align with the various mine planning phases and sequences. In particular, a long-term water plan would outline the water activities and preparatory steps and investments required to support the delivery of a long-term mine plan and a continual water supply. For example, a proposed mining schedule and layout may be constrained by achievable ore body dewatering or waste rock handling requirements, and a long-term water plan would document the business case for those site water management aspects and inform the operational water management plan. In this scenario, the operational water management plan would align to mine planning horizons and project timeframes to minimise water risks and deliver production targets while achieving environmental objectives.

The operational water management plan integrates water quantity and quality and typically provides a location to consolidate the conceptual hydrological setting and an overview of the water infrastructure system function. It details the water management measures that are in place and says who is responsible for implementing them. It records specific site water objectives against which performance can be assessed. It also records any requirements for internal and external reporting of water performance, ensures that 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 with limited editing rights to maintain version control.

Operational water management plans are not static documents, as operations have to regularly deal with change and improvements. They need to be regularly updated and reviewed as regulatory requirements and mine development scenarios change or are modified. Although with good planning those changes should not occur on a daily or weekly basis, they are likely to result in the need to modify the operational plan at least annually or in some instances quarterly.

Operational procedures

Operational procedures provide checklists of core requirements and directions for water-related work activities, which typically require daily to quarterly execution, such as a monthly water-quality monitoring schedule for a tailings dam groundwater-monitoring facility. They describe the required operational objectives and the observational and data collection activities and can also define responsibilities, water delivery targets and records management. Procedures are typically intended to be internal documents and are typically part of the environmental management system. It is essential that management systems are put in place to ensure that the procedures are acted upon; otherwise, they might not perform as intended.

Operational procedures can also be used to define the assumptions upon which the site's water account is based and, consequently, upon which management decisions are made. Procedures may also describe related activities, such as planning horizon processes or governance and auditing checklists and platforms for information and learning dissemination.

An important part of the site's operational procedures is to characterise and define the different water types that may have to be managed on the site. This provides the basis for clear water accounting and ensures that output from the site water account is consistently interpreted. Water accounts are the actual water ledger of operational outcomes, which can be reviewed and compared against the predictive water balances. Essentially, water has two states—raw (not previously passed through a task) and worked (passed through a task at least once). Given the importance of communicating with communities and regulators about the use of fresh water, operations should have a definition of the quality attributes that constitute fresh water and a record of its sources. The MCA's Water Accounting Framework for the Minerals Industry provides a consistent approach to water accounting based on water type (MCA 2014).

As with the operational water management plan, the procedures need to be kept current and relevant via regular reviews.[19]

---

19 Sections 9 and 11 outline some of the specific requirements of operational procedures.

8.0 INTERACTION BETWEEN THE OPERATIONAL MINE WATER SYSTEM AND THE CATCHMENT

Key messages

- The first step in developing a leading practice operational mine water system involves understanding the water resources of the catchment and the broader region and the interactions between the water resources and the mining operation.
- That understanding is usually gained during the assessment and development phases of the mine
  (exploration, prefeasibility and feasibility studies, construction), but is an evolving process in which the collection of more information leads to an improvement in understanding.
- Understanding the surface water systems in the catchment, groundwater resources and water supply requirements for operations and closure is critically important at this first stage.
- To ensure leading practice control of water risks, sites need to undertake comprehensive planning and technical studies and to invest in infrastructure.
- Sites need to understand the impact of post-closure landforms on water resources and water quality.

Water is a critical resource in many mine site processes, such as resource processing and dust management, and it can be difficult to secure in water-constrained environments. It can also be a liability when the mine's interactions with water bodies pose challenges to extraction and production or lead to impacts on surrounding ecosystems. For instance, in 2010, Queensland had its wettest recorded December and experienced widespread flooding. Mine pits were flooded and could not be emptied because of regulatory conditions; access to mines was closed because of floodwater; haul roads could not be used because they were too wet and slippery; and many mine employees were affected, as their houses were flooded.

Climate impacts and associated changes to the regulations significantly increase the time dedicated to water-related issues. The workloads of production and engineering teams can be increased by requirements to dewater pits, convey mine-affected water to storage and deal with wet roads. There are clear economic reasons to improve the approach to water management for better control of such risks.

Activities vary depending on the stage of a mine's life cycle. In broad terms, understanding catchment-scale risks needs to happen in the exploration and planning phases before the operation is constructed, the mitigation measures for operational risks need to be installed while the operation is being constructed or extended in the development and expansion phases, and the individual components can be optimised during the operational phase. Mine closure must consider the legacy of water-related risks.

Sections 7 to 10 of this handbook provide guidance on selecting the best available method, rather than being prescriptive about specific tools that should be used. The first step in developing a leading practice operational mine water system involves understanding the water resources of the catchment and the broader region and the interactions between the water resources and the operation (also see sections 4 to 6 for catchment risks). This work is generally completed during the assessment and development phases of a mine (exploration, prefeasibility and feasibility studies, construction), but it is an evolving process in which the collection of more information leads to an improvement in understanding.

8.1 Surface water

Understanding the surface water systems in the catchment is critically important for mine operations.[20] Operations need to collect enough baseline data to predict and monitor impacts on water systems. Sites also need to understand the impact of post-closure landforms on water resources and water quality.

Questions that will guide an understanding of the surface water context are:

- Are there specific challenges associated with the catchment's hydrological characteristics, such as extreme flow variability, or with post-closure landforms?
- What is the quality of the surface water?
- What is the framework regulating interactions with surface water?
- What ecological and social communities does the catchment support?
- What are the sensitive areas?

The consequences of not understanding the surface water context can be:

- financial: failure to obtain appropriate permits and conditions can delay a project; failure to understand and mitigate flooding risks can have catastrophic impacts on infrastructure and production; failure to understand and mitigate drought risks can reduce production
- environmental: unacceptable impacts on important ecological communities or other users
- legal and reputational: unacceptable impacts on other users.

To ensure the leading practice control of such risks, sites need to do comprehensive planning and technical studies and to invest in infrastructure. The technical topics that need to be explored to gain an appropriate level of understanding of catchment-scale risks for the operation are discussed below.

Example: The consequences of not understanding the surface water context
The consequences of not understanding the environment in which mines are developed is no more evident than in the case of the Mount Polley Mine in British Columbia, Canada.[21] On 4 August 2014, the tailings pond embankment failed, spilling 10,000 megalitres of water and 4.5 million cubic metres of tailings into Hazeltine Creek, Lake Polley and Quensel Lake. An independent expert panel found that the tailings storage facility failed because a glaciolacustrine layer about 8 metres below the base of the dam in the area of the breach was not as strong as had been assumed in the design of the tailings storage facility.

The estimated restoration and maintenance cost was C$67 million.

20 See Section 6 for an overview of catchment hydrology.

21 This example is based on IMC (2015).

8.1.1 Collect data

Collate data from existing monitoring networks, including:

- geographical information, including digital elevation models and information on topography, vegetation and soils
- climate and rainfall data from the Bureau of Meteorology and the Queensland Government's SILO database[22]
- weather information from nearby weather stations held by private enterprises, if available
- streamflow data from state agencies or other data holders[23]
- information on the water-use licence and entitlement volumes of other users in the catchment, through the relevant water regulator
- any relevant environmental data in the public domain.

8.1.2 Install monitoring equipment and acquire additional data

The review of data might reveal significant data gaps that can be filled only by installing monitoring equipment in the area of interest:

- weather stations: if the weather station is needed for air-quality modelling or to meet the conditions of a licence, it may have specific siting and measurement requirements (such as compliance with AS 2923, required by the Victorian EPA)
- gauging stations: V-notch weirs, flumes and natural control (in some cases, maintaining passage for fish may be a design constraint)
- baseline water-quality monitoring: understanding the variation in water quality requires a good record of water samples[24]
- baseline aquatic ecology monitoring: may be needed where water quality is lower than ANZECC–ARMCANZ (2000a) default values or the ecosystem is degraded.

8.1.3 Complete baseline assessments

Completing the baseline assessments requires further work on surface water hydrology, watercourse diversions, drainage and water quality.

Surface water hydrology

A hydrological study is needed to understand the range of flows. This work has three aspects that are distinct technical areas:

- assessing the potential magnitude and impacts of extreme rainfall and flooding
- assessing water availability
- assessing the potential impacts of dewatering and the discharge of surplus water.

---

22 Queensland Government, 'SILO climate data', The Long Paddock, https://www.longpaddock.qld.gov.au/silo/.

23 The NSW Office of Water has 5,000 water-monitoring stations, of which 900 provide real-time information. The Queensland Government operates a large network of streamflow monitoring stations (https://water-monitoring.information.qld.gov.au/). The Bureau of Meteorology also holds data for water resource assessments (http://www.bom.gov.au/water/awra/index.shtml).

24 The *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC–ARMCANZ 2000a) require two years of monthly water-quality data in order to capture temporal variability when determining baseline conditions.

Hydrology relies on the assessment of the extent of rainfall with a given probability of occurring. It uses the concept of 'annual exceedance probability' (AEP), which represents the likelihood of an event of a certain magnitude occurring within a certain timeframe. For example, an event of 1:100 AEP has a 0.01 probability of occurring in a year. The AEP is a statistical construct and is calculated according to specific methods outlined in hydrological manuals (see references below). Its interpretation in the public domain can be misleading, as many references might be made to the 'fact' that a 1:100 AEP event 'can' only occur once in 100 years. That is not the case. Because an event has a low probability of occurrence does not mean that it cannot occur. It is critical for engineering and environmental teams to explain clearly what the AEP represents so that risk levels are clearly understood by everyone involved.

Rainfall totals for various AEPs are calculated using methods that extrapolate historical data into less likely domains. For AEPs with reasonably high probability (typically down to 0.01), intensity frequency duration curves are used.[25] For lower probabilities (AEP < 0.01), probable maximum precipitation methods are used.[26]

Due to the large variations in rainfall distribution and the difficulty in establishing with confidence that an event might or might not occur during the life of a mine, mitigation strategies are designed to provide protection against a given AEP. Typically, the consequences of events with a range of AEPs are analysed and costed, and the mitigation strategies to avoid the consequences of each event are also designed and costed. The selected risk level against which the mine will be protected is based on a thorough cost-benefit analysis of each scenario. The lower the AEP that is selected, the higher the cost.

It is essential to understand this concept: in many cases, there will be no regulation enforcing the risk tolerance, which needs to be selected by the project team after thorough cost-benefit analysis and engagement with various stakeholders to ensure that all aspects of risk (safety, environment, production, community and reputation risks, as well as regulatory requirements) are taken into account. Note that not all parts of a mine need to be designed for the same risk tolerance. A mine water storage facility that presents a high risk of exporting contaminated water to the environment will be designed with a lower AEP than standard drainage infrastructure.

For the assessment of extreme rainfall and flooding, the key reference is Australian rainfall and run-off (IEAust 1987), a revised edition of which is expected to be published in 2015. The assessment methodology can range from the simple application of the rational method to complex hydrological and hydraulic modelling (using tools such as RAFTS, RORB and URBS for hydrology or HEC-RAS and MIKE FLOOD for hydraulics). In all likelihood, the assessment will require input from technical experts (consulting engineers specialising in hydrology and hydraulics).

The key deliverable is a determination on whether infrastructure is at risk of being flooded. As discussed above, risk tolerance depends on the type of infrastructure: tolerances will be different for a haul road and for a mining area. If flooding requires control, deliverables should also include a mitigation plan that is likely to include infrastructure for redirecting floodwater (levees). In some jurisdictions, flood control structures are regulated. For example, in Queensland a levee is mandated if a mining operation is predicted to encroach on the flood envelope of an event of 1:1,000 AEP.

A range of tools is available to assess daily water availability, including surface water models such as the Australian water balance model, but, as with flooding, this aspect is likely to need specialist input. The key deliverables are time series of predicted daily flows and their probabilities. During these assessments, the potential for erosion from natural and constructed landforms must also be considered.

---

25 See Bureau of Meteorology, Intensity–frequency–duration, http://www.bom.gov.au/water/designRainfalls/ifd/.

26 See Bureau of Meteorology, *Probable maximum precipitation,* http://www.bom.gov.au/water/designRainfalls/pmp/index.shtml.

Watercourse diversion

Mineral resource deposits often extend beneath streams and rivers. The viability of a resource project can depend on the feasibility of diverting a watercourse to allow access to a resource deposit. Diverting a watercourse may be viable where it is economically feasible (based on the total cost over the life of the watercourse diversion) and where the impacts of the watercourse diversion can be adequately mitigated and managed. Watercourses are key components of landscapes, and communities value them for their water-supply, recreation and environmental values and for aesthetic and cultural reasons. Proposals to divert them can generate community concern and require regulatory approval. In 2014, the Queensland Government published a guideline that provides technical advice on watercourse diversions associated with resource activities (DNRM 2014). Much of the guideline's content is based on research supported by the Australian Coal Association Research Program.

Drainage

Open-cut mines can affect regional drainage, and their impacts might give rise to requirements to divert watercourses and protect infrastructure from floods. Another potential drainage impact is related to the subsidence created by underground mining. The extent of impacts depends on the size of the pit and the underground mining process. In particular, in underground longwall coalmining, the roof strata above the coal seam progressively collapses to fill the void created by the mining. This results in the progressive development of shallow, trough-like depressions on the surface above each extracted longwall panel. This surface subsidence can affect drainage features, local watercourses and the extent of floodplains. Ground levels under and adjacent to watercourses and their flood channels can be lowered, which has the potential to affect the geomorphic characteristics of creek channels.

The potential flooding and geomorphic impacts of subsidence on watercourses and drainage features must be assessed through detailed technical studies and need to include the potential to:

- increase the frequency and duration of flooding of the project site and surrounding areas
- increase overbank ponding of floodwater
- create channel avulsions by changing the direction of overbank flood flows
- increase erosion and sedimentation in affected watercourses
- reduce downstream flow through in-channel or overbank ponding.

Assessment of the effects of subsidence on surface water (and groundwater) requires specialist technical skills.

Water quality

Water quality data needs to be compiled to understand potential risks to stream health and groundwater quality and to monitor the effectiveness of mitigation measures. An understanding of the risks associated with the geochemistry data should inform the design criteria and management measures and hence the risk to the receiving environment.

A geochemical assessment of the receiving environment is needed to define the elements that are naturally present in the receiving environment. The ANZECC-ARMCANZ (2000a) guidelines provide a method for determining whether exports of mine-affected water have the potential to affect aquatic health. Mine waste geochemistry and the chemicals used in minerals processing indicate which elements or substances could be present in run-off. Analysis of all geochemical data determines whether the export of mine water to the receiving environment could present risks if not managed. The water balance identifies whether water needs to be released, either routinely or as a result of floods. The risk to stream health depends on the flow and quality of water released and the flow and quality of the receiving environment. In many jurisdictions, this is highly regulated.

For more information on water quality impacts from acid mine drainage, refer to the *Preventing acid and metalliferous drainage* leading practice handbook (DIIS 2016).

A key principle for leading practice in risk management is to understand long-term impacts on water quality and flow and to go beyond identifying the main contaminants to understand the potential impact processes and sensitive phases or components in the receiving ecosystems. Without understanding the physical, geochemical and biological processes that can lead to toxicity in key receptors, leading practice might not be achieved. For mine-affected waters 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. The ANZECC–ARMCANZ (2000a) guidelines use the concept of direct toxicity assessment, which can be used to assess the toxicity of the mine-affected water in a range of organisms. A release strategy can then be designed to avoid impacts on the receiving ecosystems, enabling the proactive management of release rates and timings. In addition, it can be far more practical to use direct toxicity assessment as a predictive tool to manage releases into temporary waters than to attempt to monitor the impact of a release after the event, when remediation of the impacts may be difficult to achieve.

Releases of mine-affected water in surface water and groundwater systems often contain dissolved, suspended and bed-load particulates and surface-transported materials. Those materials may be directly toxic or create physical environmental effects, such as abrasion or smothering, or alter habitat structures. Changing geochemical environments and physical environments (for example, by exposing groundwater to the atmosphere or in wetlands) can lead to reactions that either worsen or improve the environmental condition of the water or the receiving environment.

Example: The consequences of not understanding water quality

In January 2008, central Queensland experienced heavy rainfall.[27] Water captured in Fairbairn Dam near Emerald reached the spillway height and overtopped the dam. A few hours later, downstream of the dam, huge flows in the Nogoa River broke the levy banks around the Ensham mine and water poured into several of the operational pits. The mine collected more than 150 GL of now mine-affected water.

The regulator issued a transitional environmental program permit to allow the mine to release some of the water into the Nogoa River, but the releases caused salinity increases downstream. Drinking water supplies were affected and concerns about aquatic ecosystem impacts were raised. The water quality assessment that was done before the releases were authorised was not robust enough. The Queensland Government responded by implementing a range of strategies to better predict and regulate mine water releases, including assessments of cumulative impacts.

27 This example is based on Delzoppo (2011).

8.2 Groundwater

In most cases, mining involves interactions with groundwater, which need to be assessed and managed to prevent impacts on operations and the surrounding environment, other users and the water resource. The assessment and management of groundwater can be difficult because of technical uncertainties and challenges in characterising hydrogeological controls and flow mechanisms.

Questions about groundwater that guide mining developments include the following:

- What are the characteristics of the aquifer (including depth to water, hydraulic parameters, flow direction, distribution, recharge locations, discharge locations and flow mechanisms) that need to be understood to evaluate the water risk and opportunity?
- What are the groundwater management requirements and objectives?
- What are the quality of the groundwater and its variability vertically and laterally?
- What is the impact of mining on groundwater quality?
- Are there structural and depositional geological features that may facilitate offsite migration of contaminants?
- Are there connections between surface water and groundwater (such as springs, spring-fed creeks or baseflow-fed creeks)?
- Can aquifers yield sufficient volumes of groundwater for the operation?
- What is the regulatory framework controlling interference with and licensing of groundwater?
- Are others depending on groundwater for their livelihood?
- What is the commercial value of a secure water supply for private and public landholders?
- What ecological and social communities does groundwater support, and are there groundwater-dependent ecosystems and culturally significant sites?
- What information is needed to determine the sustainable yield and the maximum level or rate of change of groundwater that will need to be set and maintained to protect social, environmental and economic values?
- What are the potential cumulative effects?
- What are the longer term impacts from groundwater contamination, and when might they occur?
- Are there specific challenges in obtaining information that will characterise aquifers and groundwater flows?
- How much hydrogeological knowledge is needed to manage the range of effects and impacts?

The consequences of not understanding the groundwater context well enough can be:

- Financial: failure to obtain appropriate permits and conditions can delay a project; failure to understand and manage groundwater dewatering requirements or failure to maintain pit slope stability can lead to costly delays or catastrophic impacts on infrastructure and production; failure to understand and mitigate the drawdown of neighbouring aquifers can affect the ability of the mine to keep operating.
- Environmental: unacceptable impacts on important ecological communities (such as groundwater-dependent ecosystems and stygofauna).
- Legal and reputational: unacceptable impacts on other users.

The flooding of the Browns Creek mine in the central west region of New South Wales is an example of possible consequences when groundwater risks are not understood. In 1999, mining operations intersected a limestone aquifer. The mine flooded within hours and was subsequently abandoned.[28]

The key risks of not understanding the groundwater systems are:

- uncertainty about the volume of groundwater flows into mine workings
- uncertain geotechnical stability of mine workings
- uncertainty about controls of groundwater quality associated with mine workings and waste streams, particularly waste rock and tailings
- degradation or damage to groundwater-dependent ecosystems through changes to flow or quality
- uncertainty about the aquifer's responsiveness to pumping, with implications for capital and operating expenditure
- the possibility of designing a project that cannot be permitted or approved
- unacceptable impacts on neighbouring properties' water supply
- unacceptable business risk caused by low water-supply security.

Leading practice controls of these risks are early planning, technical studies (such as baseline studies and studies of temporal variation, responses to extreme events and geochemical conditions), and infrastructure. It is fundamental that a multidisciplinary team (including mining engineers, mine geologists, geotechnical engineers, ecologists, geochemists and groundwater and surface water specialists) be formed to identify and accommodate groundwater-related risks and to provide early information to ensure the minimisation of regulatory and approvals risk and better management of stakeholder expectations. Addressing issues such as the risk of slope failure, including safety consequences for personnel and increased costs to owners, requires specialised technical skills. If groundwater discharge from the site is necessary, regulatory approval will be needed, so allowance needs to be made for field studies, analysis and reporting. The engagement of a multidisciplinary team early in the mine's life cycle will deliver appropriate plans, thereby offering significant cost savings.

Groundwater systems are complex, and targeted investigations with sustained, often comprehensive monitoring are often needed to adequately understand the processes that shape the groundwater resource and its connectivity with other water resources and the environment. Groundwater management requires the collection and review of data and a continual improvement of the hydrogeological conceptualisation to support the improvement of water management systems. The technical topics that need to be explored as part of this phase and the associated activities are discussed below.

The discussion in Section 8.1.3 on water quality and drainage is also pertinent to groundwater and should be reviewed.

28 See ANL Pty Ltd, Browns Creek mine, http://anlscape.com.au/brownscreek.

8.2.1 Collect publicly available information

Access to information and data is essential for understanding groundwater systems and critical for effective groundwater management and use. Ready access to temporal and spatial data to monitor trends in groundwater condition and to evaluate the effectiveness of management plans, strategies and actions is particularly important.

The *Water Act 2007* charged the Bureau of Meteorology with the task of collating, standardising and disseminating national water data, including key groundwater data described in the Water Regulations 2008. The legislation provides a mechanism for developing uniformity in datasets among jurisdictions, which is a foundation for developing consistent approaches to groundwater management.

The bureau is developing the Australian Water Resources Information System to collate, standardise and house groundwater and related data and is collating essential contextual data for groundwater bore construction and hydrogeological stratigraphy through the National Groundwater Information System. The two systems include:

- public registers of groundwater bores (such as those of the NSW Office of Water)
- water resource plans and water sharing plans
- the National Atlas of Groundwater Dependent Ecosystems (CSIRO)
- applicable government policies, such as the Environment Protection and Biodiversity Conservation Act water trigger, the NSW aquifer interference policy and the Western Australian *Water in mining* guidelines
- groundwater assessments from projects
- the groundwater bore census

8.2.2 Install monitoring bores

In many cases, there will be insufficient data available to evaluate the hydrological conditions and develop practical management plans and objectives. Additional data will need to be collected for assessment programs, which will require:

- drilling to identify aquifers and aquitards and their physical and chemical properties
- installing groundwater monitoring bores[29]
- collecting baseline data, including groundwater level (pressure) and water quality data, over a range of seasonal conditions.

8.2.3 Complete baseline assessment

Complete the baseline assessment:

- Determine geological features and establish the hydrogeological domain, aquifers and aquifer properties.
- Determine the depth to water, water pressure, flow directions, recharge rates and the influence of rainfall and characterise water quality.
- Develop a conceptual hydrogeological model of groundwater on the local and catchment scale that considers recharge and discharge, interactions between aquifer units and interactions with surface water, groundwater-dependent ecosystems and other groundwater users.

---

29 See Minimum construction requirements for water bores in Australia (NUDLC 2012).

- Develop analytical or numerical groundwater models, if relevant, that test the conceptual model (more details are provided below).
- Refine monitoring programs based on the outcomes of conceptual and analytical or numerical modelling.
- Understand the interactions between the mine and groundwater (depletion of significant water resources, dewatering, depressurisation requirements). If dewatering is required, develop a plan for the necessary infrastructure and the disposal or storage of that water (is reinjection downstream possible?). In addition, understand the potential geochemical reactions that may take place as a result of dewatering.
- Understand water licensing and the bore census. One aspect of this is to ensure that those who use the resource are clear about the legal nature of water entitlements. The processes by which access to groundwater is enabled, the legal status of that access, and the rules and costs that apply to extraction need to be transparent and accountable.
- Review the aquifer interference policy if relevant.
- If depletion is predicted, develop a mitigation plan (for example, by establishing make-good agreements) that considers policy and licensing requirements.

In most cases, the groundwater baseline assessment will be undertaken by technical specialists (hydrogeologists and hydrochemists, as well as hydrologists and ecologists). It is critical to document the methods for collecting all data, including data related to the quantity and quality of water within the aquifer systems.

8.2.4 Predict changes to groundwater conditions

The magnitude of a groundwater system's response to the changes introduced by mining depends on a range of factors: the duration and extent of mining, the hydrogeological properties, the connection with surface water features such as rivers, and the operational and post-closure landforms.

There are various options available to predict the rate and quantum of change associated with groundwater stress. Empirical, analytical and numerical models can be applied to provide various degrees of confidence and accuracy for a modelled scenario or range of possible outcomes. A good predictive model requires a sound conceptual understanding of groundwater conditions and the likely range of variables and parameters that could occur. The uncertainties relate to hydrogeological knowledge and operational changes over time that modify the volumes and rate of change.

A groundwater model is any computational method that represents an approximation of an underground water system. While groundwater models are, by definition, simplifications of real systems, they have proven to be useful tools for addressing a range of groundwater problems, such as assessing the impact of a project on aquifers and groundwater availability, quantifying the effectiveness of mitigation strategies and selecting the most appropriate monitoring locations. They are effective tools to support decision-making.

Numerical modelling has advanced significantly over the past decade, and the finite element and finite difference models are suitable for simulating and predicting outcomes in most hydrogeological environments and aqueous phases. However, the groundwater model needs to be fit for purpose, and the margin for error needs to be understood when interpreting the results. It is unlikely that a model developed to address a specific requirement or objective will be suitable for wider application without further calibration and enhancement. The application of numerical modelling is discussed in the Australian groundwater modelling guidelines (NWC 2012).

The development of a groundwater model requires the following steps:

- Define the modelling objectives and use the available data to establish the confidence level that will be achieved.
- Conceptualise the hydrogeological system, which involves identifying and describing the processes that control or influence the movement and storage of groundwater. This includes an analysis of surface water –groundwater interactions.
- Develop the model, which translates the conceptualisation into a mathematical and numerical modelling environment.
- Calibrate the model, which is an iterative process to obtain the parameters and boundary conditions that yield results matching historical observations.
- Test the accuracy of the model's predictions under conditions that represent the predictive scenarios as closely as possible. In practice, this is difficult to achieve before a mine is operational and is often replaced by a validation process once there is enough information from the affected or stressed system.
- Develop predictive scenarios designed to answer the questions posed in the modelling objectives. For instance, if the objective is to determine the maximum sustainable extraction from an aquifer, the model can be used to derive estimates of drawdown, loss of baseflow and reduction in water availability to groundwater-dependent ecosystems for various levels of groundwater extraction and future assumptions about climate. If the objective is to design a mine dewatering scheme, the model can be used to optimise the rate at which groundwater should be pumped out, the number of bores and their location.
- Document the different stages of model development, describing all data collected and information created through the modelling process.

It is important to understand the model limitations, model error and primary model sensitivities and uncertainties before interpreting the results to deliver groundwater management objectives and solutions, such as for dewatering, water supply and tailing dam contamination. Numerical models should be updated and recalibrated frequently and, in some cases, used to establish further investigation requirements.

8.3 Environmental values

Environmental values of the surface water and groundwater systems need to be compiled. The values are the qualities of the systems that need to be protected from the effects of the operation to ensure that aquatic ecosystems and waterways of agreed importance are maintained, impacts on ecosystem services are minimised and the waterways are safe and suitable for their intended uses. They reflect the ecological, social and economic values and uses (such as for swimming, fishing or agriculture) of the water resource. Environmental values of groundwater systems are also important for groundwater-dependent ecosystems, and many surface water systems are supported by baseflow from groundwater. The values also reflect whether or not the mining activities are in undisturbed or disturbed catchments.

Water-quality objectives should be compiled if they are relevant for the location. They are measurable indicators of the characteristics needed to protect the values of particular waterways. They can be defined for a range of physical parameters (such as turbidity, suspended sediment and temperature), chemical parameters (dissolved metals, phosphorus, nitrogen, biochemical oxygen demand, toxicants) and biological parameters (algae, diatoms, macro-invertebrates, fish), as well as other measures of catchment condition (erosion levels, riparian vegetation, channel morphology).

For water-dependent ecosystems, a significant impact is likely if the predicted change in water quality is greater than that in 'moderately to slightly disturbed' systems. The predicted water quality indicators should be such that they remain within 80% to 95% of the ecosystem protection guideline values listed in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC–ARMCANZ 2000a). Note that other thresholds may apply where changes in water quality may affect other matters of national environmental significance, such as threatened species or ecological communities.

8.4 Water resources and supply

In many cases, the mining operation will need to import water from external sources to balance the difference between its requirements (such as for processing or dust suppression) and its water availability from collected rainfall and run-off and groundwater interception, or will have to provide water of a specific quality. There will be variations in many of the inputs and outputs of a mine water system. They will determine whether there is potential for a water shortage, a surplus, or both at different times. Water storage provides buffering capacity for times when supply is greater than demand and vice versa.

The water quality requirements of the minerals industry are different from those of utilities, agriculture or other industries. The minerals industry can often use lower quality water, which means that it does not necessarily need to compete with other users for water allocations. There is also potential for importing low-quality water from other industries or mines, thereby reducing the seller's requirements to find strategies for the management or disposal of that water.

Example: Beneficial use of mine water

In the Middlemount region in Queensland, the Capcoal mine, operated by Anglo American, supplies low-quality mine-affected water to Middlemount mine, a joint venture between Peabody Energy and Yancoal.[30]

Middlemount mine had identified a need for additional supply of water to its processing plant, which does not require high-quality water. The Capcoal mine was holding excess mine-affected water. The mines decided to set up an arrangement whereby Capcoal supplies a volume of mine-affected water as long as its inventory remains above a predefined target. Water balance modelling was undertaken to quantify the probability of insufficient inventory at Capcoal, which was low.

This scheme has dual benefits: Middlemount mine secures its water supply at low cost (the only cost is related to infrastructure and pumping), and Capcoal reduces its liability related to excess mine water inventory.

Questions that guide the development of a water supply strategy are:

- Are there specific challenges in understanding the mine water system inputs and outputs and the mine's water demands, in terms of both volume and quality?
- What is the demand horizon, and where are the broader water-supply options? Are there any opportunities to share or trade water with third parties?
- Who are the other users in the catchment, and where do they source their water? Will there be competition with other users, or are there opportunities for synergies?

30 This information was supplied by Anglo American.

- What is the regulatory framework for water resources planning and allocation? Does the region have a water resource plan or equivalent?
- What is the commercial value of secure water supply for private landholders?
- What is the regulatory framework for the management of surplus water? Is the release of mine-affected water allowed? If so, under what circumstances?

The consequences of not understanding the water resources and supply context can be:

- Financial: failure to understand water-supply requirements can lead to water deficiency and stop production; failure to understand potential water excess can stop production and can lead to expensive (suboptimal) investments in water supply to make up the difference
- Environmental: unacceptable impacts on important ecological communities or other users from water use or on environmental values from releases of mine-affected water caused by surplus water
- Legal and reputational: unacceptable impacts on other users; water surplus can lead to noncompliant discharges.

The risks of not developing an appropriate water supply strategy are that:

- there is not enough water to meet requirements
- too much water leads to impacts on production because the resource cannot be accessed (the production pit is flooded) or to an unacceptable impact on ecosystems through noncompliant water releases, leading to a loss of regulatory and social licence to operate
- required licences and agreements are not in place or cannot be secured
- competition with other users prevents access to a water resource.

Leading practice controls of these risks are investment in early knowledge of the ore body, planning, technical studies, infrastructure and stakeholder engagement.

To understand and quantify mine water system inputs, outputs and internal demands, the site water balance needs to be analysed. The level of detail and the selection of appropriate tools depends on the complexity of the system and the target set for water-supply reliability (for instance, the mine must have sufficient water available for its operations 95% of the time). 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.

8.4.1 Collect data

The data that is needed is:

- the surface water and groundwater context, as discussed above
- the water resource planning process for the region of interest, with the water resource plan if one is available
- all licence and statutory requirements and water allocation processes and rules for the region
- the water-quality requirements of each internal demand and the consequences of not meeting those requirements
- information about water markets and potential water trading.

Water trading is an evolving field and so far has been largely confined to the trading of water for irrigation. However, water markets are predicted to expand and might present opportunities to secure new sources of water or to sell excess water. Water brokers facilitate the buying and selling of permanent and temporary water in New South Wales, Queensland, South Australia and Victoria.

8.4.2 Model the water balance

In most cases, a model will need to be developed to represent the mine water system and to calculate, at given time intervals, its inputs, outputs, internal demands and water-quality characteristics (see also Section 11.2.1). The model design is dictated by the system's complexity and the level of reliability that is required. In some instances, a simple spreadsheet meets the requirements and the work can be performed internally by the project team. For more complex problems, specific software and skills are needed, and assistance should be sought from technical specialists.

The model must include all major components of the water management system:

- climatic variability, captured as long time-series of rainfall and evaporation data[31]
- catchment run-off and collection
- inputs from mine dewatering
- pump and gravity transfers
- design information about pits (surface area and volume for the range of water levels, from empty to full, often referred to as 'stage-storage curves')
- internal water demands (dust suppression, wash-down, processing and so on)
- objectives for the mine water system—supply reliability for internal water demands, discharge allowance (such as no discharge or discharge conditions), water-quality targets.

The model should be used to assess the performance of the system by analysing some key performance indicators, which will be site-specific but are likely to include:

- the reliability of supply to meet internal demands under various climate scenarios and volumes of additional water to be imported from external sources
- the frequency at which storage capacity is exceeded and the volume of additional storage capacity that is needed to reduce that frequency to an acceptable level
- the frequency at which the mine will release water in compliance with its environmental obligations, if any
- the impact of potential water management strategies on the performance of the system (for example, the use of a dust suppressant agent might reduce water demands for dust suppression and lead to an increase in the reliability of supply).

8.4.3 Analyse results and develop strategy

Results from the various scenarios in the water balance model need to be analysed to select the most appropriate water management strategy. A multidisciplinary team should examine the results and reach a consensus by comparing the advantages and disadvantages of each water-supply option. The cost of water supply must be included to provide a complete cost-benefit analysis. In a leading practice approach, water-supply cost considerations also account for economic impacts on other parties, as well as non-financial social and environmental impacts (Evans et al. 2006). Furthermore, any liability associated with post-closure arrangements for the supply of water to communities should be fully costed to ensure that the company is aware of the full extent of those commitments.

31 Most weather stations installed at mine sites measure solar radiation. Those measurements can be used to derive evaporation data, rather than relying on monthly averages from distant weather stations. See Food and Agriculture Organization of the United Nations (FAO), *Guidelines for computing crop water requirements: Chapter 3, Meteorological data, http://www.fao.org/docrep/X0490E/x0490e07.htm.*

8.5 Cumulative impacts

Many mining operations exist in areas where there is a concentration of activities due to exceptional mineral or coal assets, proximity to transport and export infrastructure, and the presence of sufficient energy sources to support these activities. Cumulative impacts arise as the result of the activities of multiple operations (mining and non-mining) and may affect community, environment, infrastructure and housing availability. As discussed in Chapter 5, cumulative impacts most often need to be addressed through collective planning and action, and this can provide a significant challenge for individual operations. For mining operations in areas where there is a concentration of activities, there will be cumulative impacts on water, for instance, in the form of impacts on water quality or on groundwater levels. In the Hunter Valley in New South Wales, the coal industry's participation in the Hunter River Salinity Trading Scheme is a good example of government legislation supporting collective planning and action (see Hunter River case study in Chapter 5).

The understanding, assessment and management of cumulative environmental impacts is becoming an area of greater focus by both industry and government. While the concept of cumulative impact assessment is not new, the design of such assessment and associated project requirements continue to evolve. The consequences of a poorly designed or inappropriate cumulative impact assessment and management approach can be significant, including increased and unnecessary costs, project delays, loss of community confidence in company water management, greater project uncertainty for proponents and ultimately suboptimal economic and financial returns to the region and the state.

Questions that will guide the understanding of potential cumulative impacts are:

- Is a cumulative impact assessment required? The assessment of cumulative impacts should only be undertaken where there is a likelihood of significant impacts on identified and agreed environmental, social or economic assets from more than one activity.
- Are there other water users in the area of interest? Cumulative impact assessment should be based upon the likelihood of the cumulative effect of multiple water users to cause a significant impact on an identified asset or sensitive receptor.
- Is it possible to collaborate with the various stakeholders that are concerned with the key assets at risk of impact?Cumulative impact assessment requires a collaborative process with ongoing engagement of all concerned parties and may require a collaborative approach to data sharing, monitoring and, if required, mitigative actions.
- Is there sufficient technical undestanding of the potential cumulative impacts?

The consequences of not understanding potential cumulative impacts can be:

- Financial: failure to consider cumulative impacts on water resources can delay a project.
- Environmental: unacceptable impacts on important ecological communities or other key assets from cumulative impacts of water management.
- Legal and reputational: unacceptable impacts on other users, or irreversable impacts on key assets.

Leading practice controls of these risks are planning, technical studies and mitigation strategies. Analysis of cumulative impacts of water management should include:

- Spatial and temporal boundaries.
- Surface water–groundwater interactions.
- A robust risk-based process to determine the assets or sensitive receptors that may be materially impacted by the proposed activity.
- Collective agreement on high-value environmental, social and economic assets at risk of cumulative impacts.
- The range of activities to be monitored and managed, and agreed arrangements for access to information related to all activities.

- Forecasting of the impacts of all activities; accounting for and forecasting the impacts of third-party activities can be difficult if insufficient information is made available to inform the assessment or to enable robust assumptions to be made.

8.6 Mine closure

The mine closure plan evolves and is revised over the life of the operation. There will often be a range of water-related aspects that need to be considered to ensure that there is no potential residual risk to environmental and community values. For most mines, assuming that contamination risks related to tailings storage facilities, waste rock dumps and industrial areas have been addressed[32], the key water-related closure risk will be the interaction between the voids (mine pits left by mining), final landforms and all surrounding water bodies. A critical question to answer is whether the final water balance will be positive (the voids keep filling with water), in which case there is a risk to the surrounding environmental values, or whether it will be negative (the voids lose water), in which case the objective of keeping voids as a lake cannot be met.

The core objectives of mining void rehabilitation should be to:

- render the voids and final landforms safe, stable and non-polluting, posing no environmental, safety or health risks (one key aspect is related to the export of contaminated water to the environment)
- maximise any potential future use of the area, if possible
- develop a solution that is sustainable and does not require intensive ongoing management, such as ongoing water treatment (which might be difficult to achieve with a positive water balance or mine-affected groundwater).

Studies need to be done to demonstrate that the rehabilitation plan will ensure that the voids and final landforms are safe, stable and non-polluting. A study of the interactions of the final voids with surface water and groundwater is particularly important.

Questions that guide an understanding of potential interactions between a final void and water resources are:

- Will the currently planned voids collect enough surface water or groundwater to maintain a permanent water body? If so, is there any risk that discharges of mine-affected water will contaminate surface water or groundwater? If so, what is the AEP of spills? What is the expected water quality over the medium and long terms? Will water affect long-term void stability?
- Will the voids collect groundwater from surrounding aquifers or export water to them? What is the expected impact on the aquifers or on other users?
- If there are impacts and they need to be managed by additional investments, how does the cost of the amended solutions compare with other solutions, such as totally backfilling the voids or increasing the catchment area to maintain the water level and improve water quality? Voids are generally not totally backfilled within a mine's lifetime because of the prohibitive cost of earthwork operations, but are there other options for delivering better closure outcomes?
- Are there other planning, engagement and rehabilitation solutions that could provide beneficial uses or facilitate lease relinquishment at closure? What licences and approvals would be required?

Many open-cut mining operations elect to let their pit voids fill with water from rain or from diverting a water source into the void to create a new lake. Creating a post-mining water body seems to be a practical solution

32 See the *Mine closure* leading practice handbook (DIIS 2016).

that can provide beneficial use to surrounding communities, but it raises a range of issues and challenges, particularly where climatic conditions are highly variable, evaporation rates are high and mine-affected water is of poor quality. Water and chemical balances will be needed in order to understand the risks posed by rehabilitation plans.

Mining often results in permanent changes to the landscape and its hydrological function. That, in turn, may have significant long-term consequences for the surrounding environment following closure. Leading practice mining operations plan final landforms, design their shape and geochemical and geophysical attributes, and construct them with a view to minimising the long-term impact of the mining operation. The operation needs to manage and review the water performance of the final landforms over the mine's life cycle and not simply manipulate the landscape after mining ceases.

The consequences of a poorly designed or inappropriate mine closure plan, as it relates to final voids and water interactions, can be:

- Financial: increased financial liability from poor void rehabilitation planning or a requirement for water treatment in perpetuity
- Environmental: unacceptable impacts on water quantity or quality
- Legal: the mine cannot be relinquished until the basic objectives of rehabilitation are met.

Leading practice controls of these risks are technical studies and the development of appropriate mine closure plans. The steps for the rehabilitation of final voids and relinquishment are as follows:

- Undertake detailed spatial analysis, including life-of-mine plans and profiles of proposed voids and all void catchment areas.
- Develop a conceptual model of interactions between the voids and surrounding aquifers using the information compiled as part of the groundwater baseline assessment.
- Analyse the water balance. Ideally, the water balance model used to develop the water strategy should be adapted to study mine closure aspects.
- Develop a range of water- and solute-balance scenarios for several climate scenarios (for instance, dry, wet and median scenarios) or perform stochastic modelling. Review the latest climate modelling to determine how to include the impacts of climate change (for example, increased total rainfall for the wet scenario).
- Analyse whether final voids are stable, safe and non-polluting by deriving time series of void water levels and approximate void water quality for the range of climate scenarios. Use the data to assess the risk of overtopping and discharging contaminated water to surface water or groundwater. Engage with relevant personnel to assess any potential stability issue induced by water. Ensure that all assumptions that were used in the modelling are well documented and outline further investigations that are needed to address the key unknowns.
- Where risks are identified, do research to identify management strategies, such as aquifer sealing (grouting, surface hydrologic barriers, often referred to as 'neutral barrier' technology), pit wall sealing (shotcrete), decreasing or increasing catchment areas (earthworks) and controlling evaporation losses (floating barriers, water additives). Document the risks and opportunities associated with each strategy in a risk and opportunity matrix. Derive approximate costs for the strategies and compare them with the cost of totally backfilling the voids.
- Use predictions of key voids' water levels to assess how much additional surface water inflow (if any) would be needed to maintain a permanent pit lake. Assess any potential downstream impacts or benefits (such as flood reduction).
- Determine potential beneficial uses from pit lakes (such as aquaculture).
- Assess any other risk from maintaining pit lakes, such as overtopping to the receiving environment, safety risks associated with uncontrolled access, or impacts on fauna.

The mine closure plan can also include commitments to meet the ongoing demands of other water users. When a mine is built, in some instances, arrangements are made to provide water to surrounding communities. The mine closure plan must include all water-related commitments, including the infrastructure that will be needed to supply community water needs into the future.

Case study: The Ngalang Boodja Mine Lake Aquaculture Project

Local innovation and vision have led to Yancoal Premier Coal taking a leadership role in the establishment of the Ngalang Boodja Mine Lake Aquaculture Project—a research aquafarm that implements leading technologies for the sustainable rehabilitation and future commercial use of mine voids.

The key aims of the project were to develop long-term, environmentally sustainable solutions for existing mine voids with water acidification problems and to initiate employment, commercial and business enterprise opportunities for the Collie community in Western Australia.

This initiative links large-scale mine rehabilitation with Aboriginal education and training to create a feasible, sustainable and vibrant new centre for marron farming in Collie.

The project involves pumping acidic water from the mine lake into a limestone treatment system. The aquaculture project has used wastewater that would otherwise not have been used, to research, establish and operate a commercially viable marron farming business. This also reduces the pressure on and use of good-quality water.

The project has developed techniques in water treatment while increasing Western Australia's marron production and providing the additional benefits of education in aquaculture to local Aboriginal enterprises.

The project will also improve water quality by increasing nutrient concentrations and pH levels in aquaculture. This will directly benefit the water quality and ecology of the acid coalmine lake through increased algal communities, providing a greater energy base for aquatic life higher up the food chain.

The project showcases how aquaculture can integrate with mining operations to deliver tangible benefits to the local community and more broadly. It also has the potential to create a freshwater industry development hub that will play a critical role in the growth and profitability of this industry in Western Australia.

Phil Ugle, CEO Ngalang Boodja Enterprises, at the Collie aquafarm.

9.0 DESIGN AND BUILD THE MINE WATER SYSTEM

Key messages

- Detailed design of the mine water system is required so that the conditions of the project approval, environmental licences, water licences and other legal requirements are met.
- The key water management infrastructure—such as creek diversions, mine water storage and mine dewatering, erosion and sediment control, groundwater dewatering, storage of mine water, and the supply of high-quality water or mine-affected water for various demands—that will protect the operation against key catchment-scale risks must be well identified, designed for the agreed risk tolerance and in place before mining can proceed.
- Data collection and monitoring are critically important at this operational stage.

Once the catchment context is well understood and documented and all required approvals have been obtained, detailed design and construction of the operation can proceed. The requirements for key water management infrastructure, such as creek diversions, mine water storage and mine dewatering, that will protect the operation against the key catchment-scale risks should be well identified and designed and must be in place before mining can proceed.

This section is concerned with the water-related activities that must occur during the detailed design, construction and commissioning of a new operation or of an operation expansion. Detailed design is required so that the mine water system will meet the conditions of the project approval, environmental licences, water licences and other legal requirements. In this phase, the risk-based design criteria are finalised and design decisions based on cost-benefit analyses are made. Key activities that must be completed include the design and installation of all infrastructure that will be used to manage mine-affected run-off, erosion and sediment generation; the export, groundwater dewatering and storage of mine water; and the supply of high-quality water or mine-affected water for various demands. The installation of infrastructure often occurs in a staged approach that aligns with the mining phases.

9.1 Surface water

Surface water must be segregated from other water, and erosion and sediment must be controlled.

9.1.1. Effective segregation of mine-affected and non-mine-affected water

In most jurisdictions, run-off flows that do not come into contact with the mine's activities are considered high-quality water that can be passively released to the environment, provided adequate erosion and sediment control structures are in place. In practice, this means that mine-affected and non-mine-affected flows must be effectively segregated. Mine water planning and general mine planning must be integrated to clearly define the segregation between the high-quality and low-quality water components, which is based on the extent of disturbed and undisturbed land, and to select the nature, size and location of diversion and drainage infrastructure. The principles that underpin effective segregation are:

- minimising land disturbance, designating roadways and laydown areas and restricting access to undisturbed areas
- progressively rehabilitating and stabilising mine-disturbed areas
- diverting non-mine-affected flows if that leads to a significant reduction of the catchment area reporting to disturbed areas.

The construction of diversion drains and channels, typically upslope of disturbed areas, minimises the extent of run-off flows that come into contact with mining activities. Design criteria for the drains and channels largely depend on a site's complexity and local legal requirements but are based on standard engineering criteria, such as the requirement to safely convey flows of a given probability of occurrence.

A key deliverable from this activity should be an accurate description of catchments and subcatchments, land use within each subcatchment, the nature of associated flows (mine-affected versus non-mine-affected) and the outlet point of each subcatchment; and field verification of subcatchment boundaries and outlet points (for instance, pipes or culverts under a haul road for transfer downstream, erosion and sediment control structures for release into the environment or for capture in storage).

The work must be supported by further and extensive field verification to gain confidence that the catchment mapping accurately reflects the quality of run-off flows and their fate (passively released to the environment, captured in mine water storage or so on). The information should be provided as detailed catchment maps in a GIS environment, displaying a range of attributes: aerial photos, contours, catchment and subcatchment boundaries, main flow pathways showing flows of mine-affected and non-mine-affected water and whether a flow is captured in the mine water system or not.

The maps can then be used to document the catchments that contribute to the mine water inventory and to document the catchments that do not generate mine-affected water and will be managed through the sediment and erosion management plan.

9.1.2 Erosion and sediment control

Even in undisturbed catchments, sediments are encountered at natural background levels and the receiving environment has adapted to those sediment loads. However, sediment can become a contaminant if it exceeds the limits of acceptable change within receiving waters, leading to environmental degradation. Sediment usually consists of fine material (comprising clay and silt-sized particles) and coarse material (comprising coarser silt and sand-sized particles). As the mine develops, new land is disturbed and drainage is altered. Erosion and sediment control needs to be in place ahead of the disturbance.

Example: The consequences of not managing sediment and erosion control
During the construction of the Dargues Reef Mine in 2013, muddy stormwater was discharged from the site on three separate occasions following rainfall. The NSW Environment Protection Authority successfully prosecuted the operators of the mine for failing to install adequate sediment and erosion control, and the operators were ordered to pay $196,000 in penalties and costs (NSW EPA 2014).

Preventing unacceptable levels of sediment from leaving the operation and entering waterways is the most important function of erosion and sediment control. The three key principles are:

- drainage control: prevent or reduce soil erosion caused by concentrated flows and appropriately segregate mine-affected and non-mine-affected flows (as described above)
- erosion control: prevent or minimise soil erosion from dispersive, non-dispersive or competent material caused by raindrop impact and exacerbated overland flow on disturbed surfaces
- sediment control: trap or retain sediment contained in run-off flows.

Effective erosion and sediment control can be achieved by following these standard steps:

- Identify the potential sources of sediment through accurate land-use mapping. This should be done when assessing the flows of mine-affected water. Land-use mapping needs to be based on standard land-use definitions. They will vary with operations, could include exploration activity, peripheral land, rehabilitated area, subsidence area, spoil (draining externally or internally), topsoil stripped areas, stockpiles, reject areas, haul roads, construction work, and tailings storage. Activities that have the potential to cause or increase erosion and consequently increase the generation of sediment from the operation include the exposure of soils during the construction of mine infrastructure (vegetation clearance, soil stripping and earthworks) and ongoing mining activities involving land clearing and the stripping and stockpiling of mine materials. Minimising the amount of disturbed land at any point in time reduces the scale of the erosion and sediment control system for the site. Progressive rehabilitation can start as soon as construction is completed, creating stable landforms not subject to the same risks from erosion as those that are not stable.

- Assess the erosion potential, which is affected by slope, soil type, the extent and duration of soil disturbance, location within the catchment and proximity to waterways. All these aspects need to be considered and combined to assign an erosion risk to each area. A key deliverable will be an erosion risk map, clearly showing high-risk and low-risk sites. An example of a simple erosion assessment are provided in IECA (2008). To determine the soil type, soil sampling and testing is required. Most NATA-accredited laboratories offer services for the measurement of soil particle size distribution, pH, electrical conductivity and exchangeable cations. Those measurements are used to assess whether a soil is dispersive or not and whether it is at high risk of erodibility.
- Identify the need for control measures and select the most appropriate type of measures, depending on whether drainage, erosion or sediment control is required (Table 5).

Table 5: Examples of effective drainage, erosion and sediment control measures

DRAINAGE CONTROL	EROSION CONTROL	SEDIMENT CONTROL
Catch drains Check dams Energy dissipators	Erosion control blankets Mulching Geocellular containment systems Surface roughening Geobinders Rock lining Rock mattresses	Vegetative buffers Sediment fences Sediment traps Sediment basins or dams

The most effective combination of measures depends on the operation's specific constraints. IECA (2008) includes fact sheets for the detailed design of control measures.

- Maintain a register of control measures, including maps of their locations and details of their monitoring and maintenance requirements. Routine inspection and maintenance of control measures must be undertaken regularly for the measures to remain effective. In general, routine inspection and maintenance are undertaken before the wet season (if the operation is in an area that has a wet season) and after significant rainfall that may have affected the functionality of the measures.

9.2 Groundwater

During the operations phase, the mine is concerned with managing flows of groundwater that interfere with mining activities or affect its ability to safely access the resource, and with meeting its environmental obligations for managing potential groundwater-related impacts. A clear operational management objective needs to be established before investigations, assessments and designs to outline the fundamental requirements of the activity and to set achievable and practical management targets. For example, dewatering is completed to address various objectives, such as maintaining dry operating conditions or dry blast conditions, lowering pit slope pressures or achieving an optimal ore moisture content. Designs, timeframes, volumes and operations depend upon these different water management objectives.

9.2.1 Low groundwater inflows into open-cut pits

When the materials forming pit walls have low permeability or the aquifers surrounding the pits have low yield, the flows of groundwater to an open-cut pit are likely to be low. In this case, a simple sump to collect inflows to be pumped out might be all that is required. 'Pump-sump' systems can be as simple as a drop cut sump in the bottom of a pit with a pump capacity sufficient to prevent pit floor flooding up to a certain level. Note that pump-sump systems are often set up to manage both low groundwater inflows and run-off flows. In that case, the pump-sump system is likely to be designed for given a rainfall event, such as 1:10 AEP storms. There will be a trade-off between the size of the sump and the pumping capacity: the larger the sump, the smaller the required pump and vice versa. There is also a trade-off between the cost of the system and its reliability. Cost-benefit analyses are often required, but in many cases production losses will outweigh pump costs. With increased trade-off complexity, specialised technical expertise should be sought.

Beyond design considerations, there are practical aspects to consider. If the pit floor cannot be driven over by heavy machinery because of wet materials (such as clays that soften when driven over repeatedly), production will be affected. Soft and wet materials at and below the watertable can be difficult to manage because they may have low permeability and not be amenable to simple dewatering by pumping. In such situations, the most appropriate approach is to drain the floor by pumping from deeper permeable zones or from deep sumps.

9.2.2 High groundwater inflows: lowering the watertable

A decision to design and operate a dewatering system to lower the watertable should be the outcome of the groundwater assessment, not an initial assumption. A well-managed investigation and design program identifies the dewatering objective, the most practical and cost-effective dewatering solution and the optimal equipment selection and construction schedule. Dewatering can be achieved in several ways:

- pumped wells or deep sumps inside the pit
- pumped wells outside the pit
- free-flowing drillholes inside the pit, the inflow being collected and pumped from one or more sumps
- drainage galleries with fans of drillholes
- pumping from older, deeper mine workings.

Depending on the size of the mine and the groundwater conditions, one or more sumps will be necessary, often in parallel with pumped wells.

Practical issues to consider when selecting a method include:

- access to appropriate locations to install and operate the dewatering wells
- maintaining nearly continuous pumping at appropriate rates
- accommodating changes in mine plans
- designing appropriate pumping and piping systems for the likely range of pumping rates and, at some sites, to accommodate aggressive water chemistry, particularly if there are acid-generating conditions
- the potential for post-operational groundwater level rebound following the cessation of dewatering
- the potential for discharging surplus water, if there is any, to the natural environment outside the mining lease, including treatment of the water if necessary.

9.2.3 Maintaining pit wall stability: depressurisation of pit walls

Pit slope design often depends on groundwater pressures in the materials behind the wall. Groundwater pressures at any point are typically proportional to the depth of that point below the watertable. For open-pit mines deeper than 100 metres, the groundwater pressures can reach megapascals, approaching or exceeding the strengths of some mined materials.

Groundwater pressure is the only property of a rock mass that can in practice be changed by engineered activities. It is possible to lower pressures with pumped or, usually, free-flowing drillholes. In some cases, this can result in steeper pit slopes without an increased risk of failure.

Reducing pressure is a cost-effective way to achieve slopes without an unacceptable risk of slope failure. The alternative of creating slopes that are unnecessarily flat for the required stability may run to hundreds of millions of dollars of additional costs over the life of a large mine.

For pits with high-permeability materials in the walls, dewatering the mine floor may also drain and depressurise the walls. However, in many situations, wall rocks might not depressurise so easily. Examples include layered sedimentary rocks in coalmines and high-permeability ore bodies surrounded by lower permeability host rocks, such as many iron ore mines in Western Australia.

9.2.4 Reinjection

Reinjection is the practice of placing groundwater extracted as part of the mining process into the same or a nearby aquifer. It can be achieved using engineering infrastructure or passive reinfiltration via local watercourses. In some circumstances, it is preferable to releasing water into surface water systems. Reinjection requires specific geological and hydrogeological conditions with the added requirement of being economically feasible. A reinjection operation should be located:

- in geology that has the capacity to receive water at a sufficiently high rate (that is, geology that exhibits at least moderate permeability)
- in an area with a sufficiently deep natural watertable
- in areas where the quality of injected and receiving waters is compatible
- 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 reinjection.

Case study: Aquifer recharge at the Cloudbreak mine

Cloudbreak iron ore mine, which is operated by Fortescue Metals Group, is on the northern fringe of the Fortescue Marsh, an extensive wetland in the Pilbara region of Western Australia. The wetland, considered nationally significant, is an important breeding site for native bird populations and is on the National Wetland Register.

Around 90% of the Cloudbreak ore body is situated below the watertable, so dewatering is needed to mine the ore. The current licensed dewatering capacity is 125 GL/year, and approximately 80% of the water is reinjected as part of a managed aquifer recharge (MAR) approach. The MAR approach has been designed to mitigate the environmental impacts of abstraction for dewatering and process water supply while conserving water resources for future use.

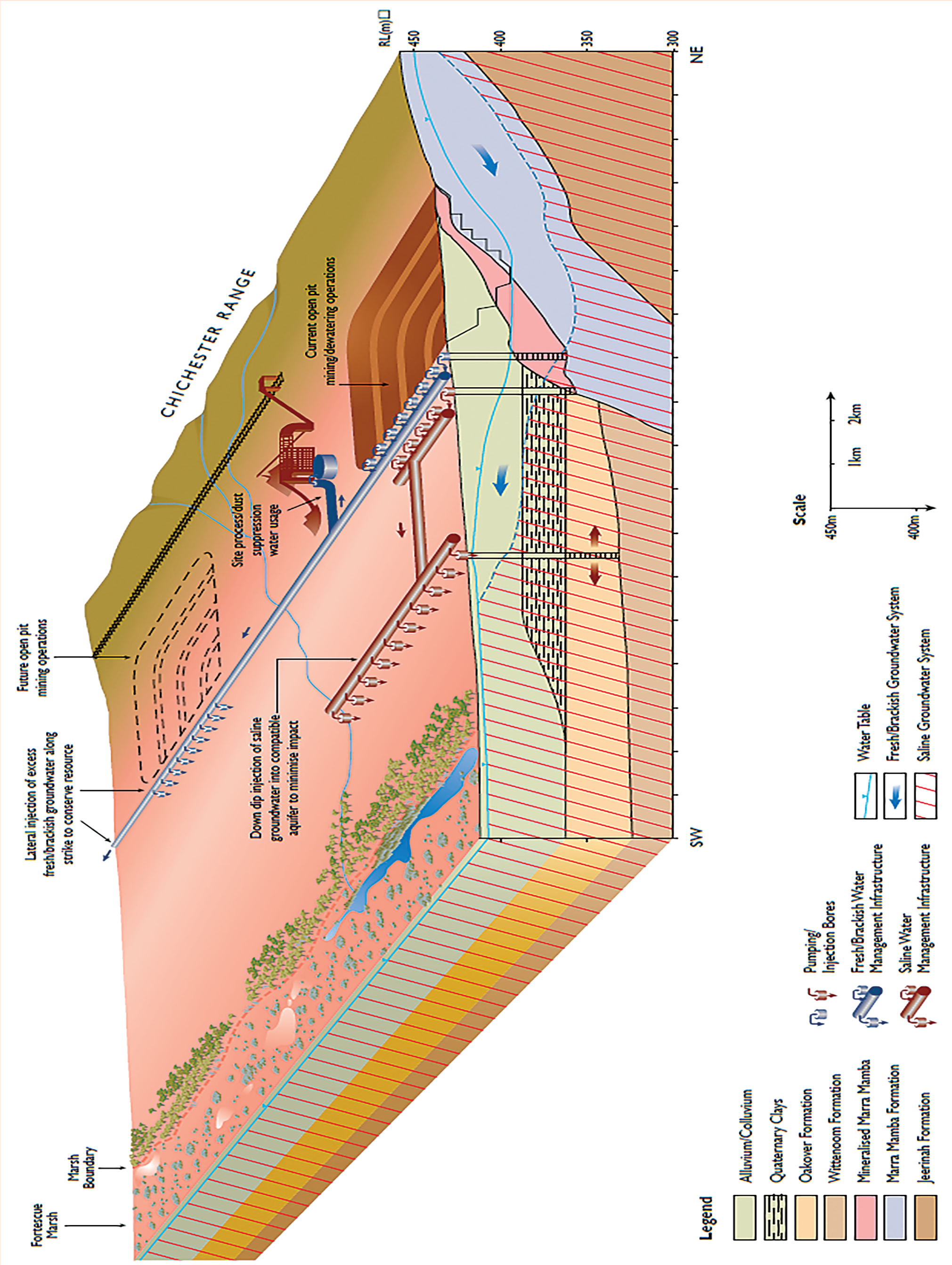
The water management system is in a complex and hydrologically sensitive environment and is designed to maintain separation of brackish groundwater from an underlying hypersaline groundwater system that extends beneath the Fortescue Marsh.

Saline water that is abstracted from mine dewatering is reinjected into the saline aquifer under the marsh to maintain the pre-mining water level in the surficial aquifer. Excess brackish water is reinjected and stored in future mining areas for future use to maximise the groundwater resource and keep the environmental footprint of the project as small as possible.

The system has been running successfully for the past seven years. Given that it manages both saline and brackish water and its current capacity, it is one of the largest and most complex MAR schemes in Australia.

Water management operates under an approved Cloudbreak operating strategy that includes an extensive network of monitoring points with specific trigger levels to warn against potential impacts to ecological receptors. To date, proactive management of the system has resulted in no trigger level breaches.

The MAR approach is providing an ongoing opportunity for advancing the scientific understanding and development of applied water management skills to a large-scale water resource management challenge. Studies have been conducted in conjunction with University of Western Australia to develop an understanding of the Fortescue Marsh, and the results are being used to improve groundwater model simulations of life-of-mine water management.



Simplified schematic of the Cloudbreak MAR scheme.

Source: Fortescue Metals Group.

9.2.5 Groundwater monitoring

A hydrogeological field work and monitoring program is typically required to manage the potential impacts of mining on groundwater and to collect data to improve the operational effectiveness of activities such as dewatering and reinjection. Such a program requires the installation of instruments to monitor groundwater levels and quality within aquifers, provide an estimate of the hydraulic properties of the aquifers, monitor the baseline and operational groundwater pressure heads at predetermined depths and monitor groundwater quality. Monitoring locations need to be selected in consultation with groundwater specialists and hydrogeologists to ensure that the monitoring is fit for purpose and addresses the key hydrogeological controls and stress activities. Achieving those aims requires:

- drilling boreholes and installing piezometers, monitoring bores and test bores
- conducting pumping tests
- sampling groundwater to measure quality parameters, such as pH, electrical conductivity, alkalinity, suspended and dissolved solids, major cations and anions, nutrients, total and dissolved metals, hydrocarbons and volatile organic compounds
- recording all information about the monitoring program in appropriate documents.

Groundwater monitoring is part of data collection requirements discussed in Section 9.4.

9.3 Mine water system

Operations must have systems in place to transfer, direct and convey surface water and groundwater for normal operating conditions and to meet the agreed risk tolerance. Climatic conditions influence the performance of the system. Managing the flows of mine-affected water to meet stakeholder expectations requires a thorough understanding of the impact of climate variations on run-off flows and volumes collected by the mine water system (water balance modelling and reporting); requires mine water systems that are designed to minimise the extent of mine-affected flows and that contain all mine-affected water to comply with environmental conditions; and requires extensive monitoring of the receiving environment and appropriate data management systems to compile, interrogate and report the collected information.

Example: Consequences of designing a mine water system for an inadequate risk level
In Queensland, rainfall in 2010 and early 2011 resulted in critical parts of a number of coalmining operations becoming inoperable. Coal production was affected to varying degrees. Some of the factors that contributed to reduced production included access roads being closed, open-cut pits and underground areas collecting excessive amounts of water, the capacity of pumping and pipe systems being exceeded, coal conveyors being inundated, some water storage dams filling to unmanageable levels and mines' inability to pump water from the mine into local watercourses due to environmental regulations.

Key activities are as follows:

- Record and monitor the input of water from external sources.
- Understand how much mine-affected water will be stored on site, from both run-off and groundwater. Ideally, the water balance model that was developed to understand the relationship between the operation and its catchment can be used or refined to perform this task. The model should be reviewed regularly and should contain a level of detail commensurate with the mine water system's complexity and the key risks. Because climate variation is the key unknown, the model should have the capability to run several climate scenarios or undertake stochastic analysis.
- Understand the quality of water that will be stored, and assign each type of water quality to specific stores, if relevant. For instance, waste rock dumps or spoil piles are often a significant source of mine-affected water at a mine site, and the quality of the run-off from the dumps might require its storage in specific structures. There is often a long delay between rain falling on waste rock or spoil and the run-off volume being collected in storage, which can pose difficulty when trying to reconcile the water balance over short intervals (week or month). Where acid mine drainage is a risk, refer to the *Preventing acid and metalliferous drainage* leading practice handbook (DIIS 2016), which provides guidance on the control of acid mine drainage.
- Understand and develop inventory forecasts and compare them with task demands. Typical demands include dust suppression in underground mining and processing plants, dust suppression for surface activities (haul roads and stockpiles), vehicle wash-down and other miscellaneous industrial demands. Demands must be monitored, ideally through adequate metering and automatic upload of metering data to appropriate software (an example is the CitectSCADA system, with export of data to process historical software). Simpler methods might be appropriate. The quality of the water required by each demand must be recorded. Water-quality tolerances for each operational demand should be defined and recorded, and appropriate management responses to changes in those conditions should be documented in operational procedures.
- Define critical levels that clearly communicate when there is a risk of inadequate supply. There will be a critical level for each source of a specified water quality. For instance, demands that rely on the supply of mine-affected water will refer to a critical level set for the mine water inventory. Demands that rely on the supply of external water will refer to operational constraints set out by the third party delivering the water.
- Report the water balance at agreed time intervals. When there is no specific stress event, monthly reporting of the water balance is likely to be appropriate. In times of stress, such as severe rainfall, the water balance might need to be updated more often. To reconcile the water balance, data on water inventory should be collected regularly. The most common method is to measure water levels in pits and dams and then convert them to volumes and surface areas (the latter for the calculation of evaporation losses). Bathymetric surveys need to be conducted regularly (every two or three years is often appropriate) on critical storage structures to update the relationships between the water level, volume and surface area. New technologies are offering new and more cost-efficient methods of measurement. For example, drones can now be flown to quickly measure the surface area of the water body, which can then be converted into a volume. The water balance needs to be reviewed to assess the risk of excess inventory and the risk of insufficient inventory. Define management options for both.
- Regularly conduct a water balance analysis for a range of scenarios that consider potential impacts to the operation's water supply, such as geochemical changes affecting water quality, climatic projections affecting water quantity, changes over time in water availability, vulnerability to shortages, and quality constraints.
- Assess the specific risks associated with each storage structure: the risk of not meeting freeboard requirements (if applicable) and the risk of noncompliant releases, but for individual structures rather than the overall site. The design of storage structures varies across jurisdictions and environmental conditions but is usually dictated by the ability to contain a required design storm event without discharging to the environment and the ability to contain the run-off of a wet season with a specific annual exceedance probability.

- In some jurisdictions, irrespective of the design requirements, release conditions must always be met. In those cases, there can be a slight disconnect between the design of storage structures and the ability to meet release conditions.
- Optimise, test and record the release strategies, along with detailed operational procedures for conducting a release. Controlled releases require sufficient infrastructure to capture and hold water pending release. Release conditions are imposed by environmental obligations. As they can be complex and must meet a range of conditions, a detailed operational procedure, with extensive testing, is essential. The performance and impact of water releases should be reviewed after each wet season (or rainfall event) to capture any change to the operation and receiving environments, and release strategies should be adjusted accordingly. Monitoring data provides the information with which to assess the releases' impacts and may lead to a reassessment of the monitoring program. This cycling back of information into the management of releases is often missed unless a noncompliance situation occurs, which is not proactive management and not leading practice.

9.4 Data collection and management

Operational managers are required to collect a large range of data to support their water management and to report on the effectiveness of their water management procedures. The extent of the data collection program depends on the operation, but there are key leading practice principles for data collection and management. In most cases, sampling is undertaken to confirm compliance with environmental obligations, to assess the environmental performance of the operation and to monitor the receiving environment. In the case of water, broadly, this requires measurements of:

- the characteristics of the surface water and groundwater receiving environment (flow and water quality parameters), often using automated monitoring and sampling devices and sampling of in situ water for analysis by a qualified laboratory
- the level and quality of groundwater
- the quality of mine-affected water
- the internal demands and other flows that are used to calculate or estimate site inputs and outputs.

The objectives of the sampling program should be determined and documented and be as specific as possible, defining the spatial boundaries of sampling (the size of area to be assessed), temporal scale (for how long) and frequency (how often). The major issues of concern (such as nutrients, metal loads and bioavailable metals) should be known from understanding the operation's context, including the receiving environment. Ideally, when deciding on the number of samples to collect and the frequency of sampling required, sufficient samples and replicates are collected to represent the full range of variability in space and over time. The essential features of a sampling strategy are to ensure that the material sampled is genuinely representative of the body of material from which it was collected, that in situ measurements are reliable, and that the integrity of materials sent for laboratory analysis has not been compromised by contamination, degradation, transformation or losses. The sampling regime must be representative of the system and the parameters of interest. The monitoring program should be reviewed regularly to assess whether monitoring locations need to be moved and whether the program still meets the requirements of the regulatory framework.

Common techniques, methods and standards for sample collection, handling, quality assurance and control, custodianship and data management are described in manuals produced by various government entities. A good example is the Queensland Department of Environment and Heritage Protection's *Monitoring and sampling manual* (DEHP 2013), which provides procedures for sampling design; sampling in the field; in situ tests and water quality measurements; sampling for water quality assessments, sediments and biota; preserving and storing samples for water-quality assessments; transporting samples; arranging laboratory analysis; and analysing and interpreting data.

Quality assurance and control are essential in both sampling and analysis. Laboratory analyses should be undertaken by a laboratory accredited by NATA (or equivalent). Only a limited number of commercial laboratories offer analytical limits of detection that are adequate to meet compliance requirements (such as the ability to measure compliance with the guidelines for 95% protection of slightly to moderately disturbed aquatic ecosystems). Biological monitoring is increasingly required. Some ecotoxicology testing laboratories can test the toxicity of mine-affected water on a range of test organisms, and some biological consultants can provide local assessments using appropriate ecosystem monitoring tools.

Many mines also install automated monitoring networks, which require extensive telemetry equipment for the remote downloading of sensor measurements (usually a source of power, loggers, a modem and an antenna). A range of companies specialise in the installation of automated monitoring.

A sampling regime generates a large amount of data that must be managed with an appropriate tool, ideally a centralised environmental database (see Anglo American Coal's case study, using EnviroSys, in Section 12). It is also important to manage metadata (for example, the changes made to bore casing height as the mine develops) and to store datasets that are no longer active (such as those from exploration bores). A high-performing data management system also has the ability to detect changes and send warnings to trigger a management response. With centralised data management, the data can be analysed to identify trends, particularly trends away from baseline; monitor the environmental performance of operations; and compile reports for communication to a range of stakeholders.

Case study: Baseline water-quality data creating value at Newcrest

Newcrest's Cadia Valley operation is in the central west region of New South Wales within the Cadiangullong Creek catchment. The open-cut mine is very close to the creek, and a 2-km long section of the creek has been diverted around the mine. Maintaining the water quality in Cadiangullong Creek downstream of the operation is a key water management objective.

Water-quality sampling commenced in 1994, and bi-annual aquatic ecosystem monitoring began in 2006. Until 2012, Newcrest reported exceedances of the ANZECC–ARMCANZ (2000a) water-quality trigger values at downstream monitoring locations. The exceedances were attributed to natural geology and agricultural impacts. However, the concentration at which there was potential for impacts on stream health had not been established.

The ANZECC–ARMCANZ guidelines provide trigger values for six different ecosystem types, along with categories for their condition (high conservation, slightly to moderately modified, highly disturbed). At Cadia, the ecosystem type is an upland river with historical mining, agriculture and forestry and is classified as slightly to moderately disturbed. The guidelines provide the method to develop site-specific trigger values (SSTVs) based on the upstream sampling record. For example, upstream phosphorus concentrations were typically 0.04 mg/L compared to the trigger value for upland rivers in New South Wales of 0.02 mg/L. In this case, the 80th percentile of the upstream values was selected as a downstream SSTV. Alternatively, upstream electrical conductivity was typically 70 µS/cm compared to the default trigger of 350 µS/cm. In this case, the default trigger was used as the SSTV. Adjustments were also made for some heavy metals based on water hardness.

The SSTVs were compared with downstream water quality to assess the impacts of the site on stream health. With the exception of electrical conductivity, only a few results were above the SSTVs. The guidelines allow for further assessment, taking into consideration results from aquatic ecology monitoring. Longer term monitoring of aquatic ecology upstream and downstream of the site showed equivalent stream health at both locations. This, combined with the absence of any long-term trends in electrical conductivity, meant that there was sufficient evidence to support increasing the SSTV to the 80th percentile of the downstream monitoring location from the default trigger of 350 μS/cm to 931 μS/cm. For the first time, the Cadia operation is now able to use the resulting SSTVs to provide a means of assessing the potential impacts of stream health, from either a single event or a long-term trend. This was made possible with longer term water-quality data and aquatic ecology monitoring from upstream and downstream locations.

Water-quality monitoring at Cadiangullong Creek downstream of Newcrest's Cadia Mine.

10.0 MAINTAIN AND OPTIMISE THE MINE WATER SYSTEM

Key messages

- Once the operation has been designed to control all high-level risks and built to control and manage all operational level risks, there can be opportunities to optimise individual components and implement a range of leading practice options.
- Water management practices are adapted to climatic conditions. In dry conditions, they focus on water efficiency. In wet conditions, they on flood management and water-quality monitoring.
- Leading practice operations return as much water with beneficial properties as possible (such as clean water or, for some uses, water containing unused reagents).
- Optimising tailings water content can help to minimise water requirements.
- Water used for dust mitigation is required for safety and production efficiency and to avoid air-quality impacts on surrounding land users and communities.

Once the operation has been designed to control all high-level risks and built to control and manage all operational level risks, there can be opportunities to optimise individual components and implement a range of leading practice options. Water management practices are adapted to climatic conditions. In general terms, in dry conditions, water management focuses on controlling evaporation losses by minimising the surface area exposed to evaporation, storing water in a small number of deep stores and improving water-use efficiency. In wet conditions, water management focuses on flood management, water-quality monitoring (to manage the risk of noncompliant discharge), and maximising the surface area exposed to evaporation by storing water in as many stores as possible. In some cases, mines have to prepare for both scenarios at different times. To achieve these objectives, specific techniques can be implemented for various mining and processing methods and typical mining activities.

10.1 Roles and responsibilities

Water-related risks cross a number of management boundaries. As discussed in more detail in Section 3.1, water management can become fragmented, with implications for multiple accountabilities, and is prone to duplication of services or ineffective planning. Water management should be integrated across all relevant departments, ideally with a coordinating body chaired by a person with adequate authority and accountability.[33]

33 See Table 4 for an overview of the tasks and responsibilities of site water teams.

10.2 Underground mining

The demands for water in an underground mine need to be analysed in detail, along with the water-quality requirements. In some instances, specific water quality will be needed to meet warranty conditions for expensive equipment. For example, in underground longwall coalmining, water for dust suppression at the coalface has to be provided at all times, cannot safely be reduced and must be very high quality to meet the warranty conditions of the equipment.

Demand analysis also needs to focus on identifying leaks, losses and conveyor requirements. There is no requirement to suppress dust on conveyors when conveyors are not operating. Specialised components for dust suppression, fire suppression and all aspects of water control in underground mining are available to automatically stop water supply when it is not needed. When the conveyor systems are not working, the sprays can stop automatically.

In coalmine operations, the motor heat exchangers are often sprayed continuously, with the sprayed water draining onto the ground and creating wet and sloppy ground conditions. This can create the need for specific maintenance tasks that cause interruptions to the longwall shearing, at a high cost. The interruptions due to maintenance can also directly affect key performance indicators of production. The water sprayed onto the heat exchangers can be recovered and plumbed back into the worked water system for reuse, yielding significant performance improvements.

Usually, the main reason for using high-quality water for dust suppression on belt conveyors is the reticulation system, which is designed to provide high-quality water only. The reticulation system can be designed or redesigned to supply mine-affected water for the sprays on conveyor belts.

To ensure that the water supply system is operated optimally and that data is collected for performance analysis, modern meters using the latest electronic technology should be installed. Such meters have the ability to communicate via a network to a central point. Real-time data can be collected using an industrial software package (such as CitectSCADA) that also provides a graphical display for continuous monitoring of operational parameters. This enables the early detection of any potential failure and allows issues to be addressed quickly.

10.3 Reuse and recycling

Recirculating water can help reduce the need to import water from external sources. The most common examples are internal recirculation within processing plants and returning water from tailings storage facilities. Almost all operations have implemented some form of recirculation. One challenge is for each operation to identify the potential for more recirculation, to build the business case for the improvement, and to secure the budget for the resources needed to implement a new recirculation scheme. Leading practice operations return as much water with beneficial properties as possible. For example, tailings water and returns from clarifiers and other process units are likely to contain unused reagents, such as flotation frothers.

The second challenge 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 for 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 from the average (containing gels or high sediment loads) and that is not communicated to the plant, significant recovery losses may occur. If that happens on a number of occasions, it can become increasingly difficult to ensure that site water reuse is optimised. It is human nature for plant operators to prioritise the use of clean water over the use of other site water to avoid operating glitches.

Water recirculation can include the treatment of the mine-affected water (water recycling) or not (water reuse). 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. They have the potential for long-term success, but there are ongoing costs associated with monitoring and maintenance, such as for periodically replacing limestone or compost, flushing the system or removing sludge. Active treatment is relatively higher in capital and maintenance costs and requires a more intensive level of monitoring. The advantages of active treatment are a high level of performance predictability during the operational life of the mine and an ability to cope with wider variations in both flow and chemical composition. Passive systems are likely to be more attractive than active chemical-based systems for water treatment after closure, when they are required to perform a final polishing role.

The optimal treatment approach depends on the water-quality requirements for either reuse or discharge. For example, most mineral processing does 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.

Case study: Water efficiency at OZ Minerals' Prominent Hill site

The Prominent Hill site is in an arid region of South Australia with average annual rainfall of less than 200 mm/year. Prominent Hill uses groundwater drawn from the Boorthanna Formation geological unit of the Arckaringa Basin. The aim of site water management is to increase the efficiency of water extracted from groundwater resources and to contain wastewater.

In 2013, the site used 6,150 ML, including for exploration, mining and processing. Water is also used for drinking and village amenities after purification through a reverse osmosis plant, and within the open pit and underground mining areas.

To maximise water efficiency, water is reclaimed and reused wherever possible. Around 1,300 ML/year is recycled out of a total volume of 6,150 ML/year. An opportunity was identified to further increase water efficiency through water recycling at the Prominent Hill process plant. The process plant is the most energy- and water-intensive aspect of the operation, using about 80% of the total volume. The mined ore goes through a sequence of stages to produce a copper concentrate. Water is used to process the ore and to separate copper minerals and gold from waste products.

In 2010, an improvement was made to the final stage in the processing plant to allow water to be reclaimed before the tailings are sent to the tailings storage facility. Over the past few years, an increased proportion of water has been reclaimed at this stage.

A series of studies were undertaken in late 2012 to determine whether excess reclaimed water is suitable for use in the flotation circuit, which occurs at an earlier stage of the process. The circuit uses a mix of air bubbles, reagents and water to separate copper from waste products.

The positive results indicated that excess reclaimed water could be substituted for raw water (sourced directly from groundwater) within the flotation circuit. In early 2013, the process was implemented, resulting in a reduction of raw water use by 75 kL/hour. Over the first full year of implementation in 2013, groundwater intake was reduced by approximately 600 ML, equating to an approximate 10% reduction.

PARAMETER (ML)	PROMINENT HILL[1]	CARRAPATEENA[2]	TOTAL
Water input	6,150	72	6,222
Water discharge off site[3]	0	3.7	3.7
Water reused	1,300	0	1,300

1 All water used at Prominent Hill is sourced from groundwater.
2 Water at Carrapateena is sourced from dams, groundwater and water cartage.
3 Water discharged off site is water from the wastewater treatment plant that is discharged to an irrigation field.

OZ Minerals' Prominent Hill site manages water as a priority in this arid region of South Australia.

10.4 Processing and tailings

Mineral processing and coal preparation put ore or run-of-mine coal through various procedures to increase the concentration of the target substance in the product. For example, gold typically makes up about 1% of mined ore, so there can be large reductions in handling and transport costs if most of the 'non-gold' can be separated out. In run-of-mine coal, the proportion of coal may be 50% to 80%, but waste or 'ash' reduction still reduces transport costs and may allow the coal to be sold as a higher quality product.

Processing usually involves several procedures in sequence to separate out different parts of the waste or to prepare the remaining concentrate for further mineral extraction. For example, gravity separation processes are used to remove rock with a different specific gravity from the target mineral; flotation uses differences in surface tension and hydrophobic character to attach the target mineral to bubbles in a froth; and solution and precipitation use specific chemical reactions to extract the target mineral from the surrounding rock.

Water is used in many separation processes, mainly as a fluid medium that allows the mineral and waste to move apart based on their different properties. Once separation has been achieved, water is often also used to make a slurry of the fine waste (tailings) so that it can be pumped to a storage facility. In coal preparation plants, the separated coarse and fine wastes are sometimes pumped together ('co-disposed') to a storage area, which obviously requires a much larger volume of water than for tailings slurry.

10.4.1 Principles of good water management in processing

Leading practice water stewardship in processing governs selecting processes, metering flows, maximising water reuse and minimising losses.

Process selection

At the design stage, the combination and sequence of processes is selected based on the physical and mineral properties of the target mineral and the host rock, the required plant capacity, and cost. The cost includes the purchase or procurement costs for water required in the processes, but there should also be consideration of the environmental and social costs of the water, such as opportunity cost to other potential users of the water, and the cost of any subsequent treatment or storage of the water as waste.

In locations where water availability is limited, dry process options, if available, may be preferred.

Metering of flows

It is emphasised several times in this leading practice handbook that good measurement is essential to good management. Ideally, all piped inflows and outflows should be continuously monitored using accurate, fit-for-purpose flow meters. Changes in flow rates can give an early indication of leaks, spills and blockages, and the interpretation of the flows in a plant's water balance can identify the demands and losses to target for improvement.

In addition to the obvious flows, some water also enters processing in the feed (ore or run-of-mine coal) and is lost in product and coarse waste. Unless that water affects the processes, it is usually sufficient to monitor it by regular sampling rather than installing a continuous in-line measurement system.

Maximising water reuse

Cost savings, as well as environmental benefits, may be realised if worked water (water used or collected elsewhere on the mine) can be used in processing to reduce the consumption of high-quality raw water. Tailings storage areas are often a major source of worked water; other sources can include mine dewatering and rainfall run-off from disturbed areas. It is normal for the quality of worked water to be somewhat degraded by prior use: salinity, acidity, alkalinity and suspended solids are common issues. The potential negative impacts of using lower quality water include increased maintenance costs due to corrosion or scale on processing plant components and reduced efficiency of process reactions; however, those impacts can often be countered by blending in enough raw water to maintain key quality criteria. The potential benefits of reuse can include reduced water purchase costs, improved reputation of the operation as an efficient water user, and significant cost savings on worked water storage and treatment facilities.

Once again, management requires measurement, in this case measurement of the water chemistry parameters that are significant to the performance of the processes and equipment. The frequency of sampling and analysis should be based on such considerations as the sensitivity of the processes and the typical variability in the recovered water; monthly or quarterly sampling and testing will often be sufficient. Changes in water quality need prompt responses. If a key parameter deteriorates, a short-term solution for continued operation may be to add a greater proportion of raw or high-quality water; however, if the change or trend continues, there should be an investigation to understand the cause and devise a remedy for the longer term.

Identifying and minimising losses

When processing includes the hydraulic deposition of tailings, that generally accounts for the greatest loss from the process water system. After decanting and some consolidation, typically some 30% to 40% of the volume in the storage facility will be water, and that quantum is mainly driven by the water retention characteristics of the tailings solids. Consequently, changing the solids concentration of the tailings slurry changes the amount of water returned but does not greatly affect the amount of water lost to tailings. However, other losses in the tailings circuit may be reduced, for example by seepage and evaporation from return water drains and evaporation from large shallow decant ponds.

Other water losses in the processing plant include leaks, spills and backwashing (such as of filters). Appropriately located catch drains can capture and reuse this water and improve safety by reducing wet floor areas.

Some water is also lost in coarse waste and in product; however, unless it affects the product's market value, the energy cost to recover the water is usually greater than the value of the water lost.

In summary, although new 'dry' processes are being developed, water use in mineral processing and coal preparation will continue for the foreseeable future, both as a process medium and for the transport of fine waste. Despite the wide range of minerals and corresponding concentration processes, the common principles of leading practice water stewardship are accurately monitoring inflows and outflows and analysing monitoring results to identify opportunities to reuse water and to reduce losses.

10.5 Dust suppression

Dust must be controlled underground, on roads, in industrial areas, around 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 and production efficiency and to avoid air-quality impacts on surrounding land users and communities. Water used for dust suppression is lost as evaporation, leaving salts that can be mobilised by run-off at a later time. Therefore, in certain areas where run-off contamination is unacceptable and cannot be controlled with appropriate drainage management, the dust suppression approach may need to use less salty water.

Leading mining operations have put significant effort into researching methods to suppress dust without excessive water consumption. The *Airborne contaminants, noise and vibration* leading practice handbook (DRET 2009) has a section that details various options for controlling dust. 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, applying dust suppressants, paying greater attention to haul road maintenance, and developing efficient spray technologies.

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

10.6 Evaporation control

Evaporation losses can be a major component of a site's water balance. In wet regions, enhanced evaporation may be necessary for the 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 storage volume ratio) and the use of underground systems, such as aquifer storage and recovery.

10.7 Leaching

One common method of product separation is leaching. Heap leaching, in particular, requires the management of large volumes of water (generally 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 and 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.

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 the long-term stability and safety of the heaps.

Solutions from which the leached metals have been recovered should be reused as far as possible, and any residual liquids should be contained or disposed of according to site licence requirements.

10.8 Energy efficiency of the mine water system

Within the infrastructure system that is used to transfer, direct and convey surface water, pumps are the primary items that consume energy. The factors that affect the overall pumping system performance include piping length and dimensions, gradients over which the pipes are installed, distances over which the water is pumped, and suitability of the pump specifications. There are opportunities to optimise pumping management through the consideration of:

- in-depth planning of water pumping and the management of the mine water system
- using electric pumps rather than diesel pumps
- evaluating all pump specifications and optimising the size of pumps and piping
- collating data about daily pumping (for instance, recording the number of litres pumped, energy consumed and operating hours).

PART V: MONITOR AND REPORT

11.0 REPORTING AND ACCOUNTING PROCESSES

Key messages

- Setting formally agreed operational and stewardship objectives and processes and implementing monitoring and reporting systems allow effective water risk management and productivity improvements.
- 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 and opportunities.
- Water accounting and water balance models are essential to underpin water management decisions and report performance internally and externally.

This section outlines the primary water reporting and accounting approaches that a leading practice operation can use to account for and report on a range of water challenges.

11.1 Corporate and statutory reporting

Correct and timely statutory water reporting is a key operational deliverable and is fundamental to maintaining an operating and social licence. The form of statutory reporting depends on the federal, state and mining district requirements.[34] Slow or inaccurate delivery of statutory reports can erode regulatory and community goodwill and introduce additional reporting and administrative requirements. Ultimately, poor delivery of regulatory and operational reporting can delay a new or amended environmental approval.

Reporting is generally required to meet the conditions attached to water abstraction licences or of environmental commitments and conditions relating to discharges of mine dewater, sediment control or acid rock drainage management and treatment prior to release. Water licences and water-related environmental licences typically require the discussion of monitoring commitments, the operational water balance and such data as groundwater levels and surface water and groundwater quality information.

The documentation of business decisions and water outcomes is typically overlooked by many mining operators. The basis for decisions, purchases, interpretations and errors provides a valuable record, which serves as a repository of corporate knowledge as staff rotate and their information is otherwise lost. For example, the basis and function of a discharge pipeline and the specific valve configuration installed and operated for a short period five years ago may present an opportunity to manage a reoccurring water risk event or serve a vital hydraulic function in the operation of the existing infrastructure.

34 Discussed in more detail in sections 2 and 5.

11.2 Water accounting

Estimating and reporting on the significant components of site water balances are fundamental parts of leading practice water stewardship.

Leading practice sites can demonstrate that they know the quantity and quality of water in their stores, the flows between tasks, 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 strategically planning changes needed in the system in response to forecast changes in operational conditions. In short, leading practice sites can account for their water and its condition.

Leading practice also requires water accounts and water performance metrics to be developed transparently, using water accounting with clear and consistent definitions of terms and with sufficient information included to allow the performance context to be understood. This facilitates efficient auditing and comparisons of water performance across different reporting periods, mine sites and other water users, and allows performance risks from changes in operating conditions to be predicted and managed.

A summary of the key requirements for leading practice water accounting is in Table 6. Those requirements are also mentioned in the case studies in this section.

Case study: Dialogue about transparent water accounting in the coalmining industry

All coalmines in the upper Hunter Valley in NSW have implemented the MCA's Water Accounting Framework (MCA 2014) so that they can report their water accounts in a consistent and transparent format.

The commitment to adopt the framework was made through the Upper Hunter Mining Dialogue, an industry-wide community engagement initiative that is coordinated by the state's peak mining industry association, the NSW Minerals Council. The dialogue began in 2010 in response to growing concerns about the cumulative impacts of mining in the region.

Eight companies operate in the upper Hunter: Glencore, Coal & Allied, Peabody Energy, Anglo American, BHP Billiton, Bloomfield Collieries, Yancoal and Idemitsu. They operate more than 15 mining complexes in the region, which produced 55% of the state's saleable coal in 2014, or around 110 million tonnes. The upper Hunter also hosts a diverse agricultural industry, several significant population centres and many smaller villages.

The dialogue provides a forum for in-depth engagement between the industry, community members, interest groups, local businesses and government to identify and prioritise important issues associated with mining in the region and the actions that can be taken to address them. Water was identified early as a particular area of interest for the community, along with emissions and health; land management; and social impacts and infrastructure. Working groups were formed to provide input into the development and implementation of projects in each of those four areas.

The decision to adopt the MCA's Water Accounting Framework was made to ensure the availability of comprehensive and reliable information about the industry's water extraction, use and discharges to provide a basis for more informed discussions about the industry's water impacts and management.

The use of a consistent framework allows simple and robust comparisons between sites, as well as the aggregation of industry data. The aggregation of data has allowed the industry's total water inputs and outputs to be considered in the context of broader water information for the region. The level of detail in reporting exceeds that prepared for any other industry or water user in the region, demonstrating the importance placed by the industry on sound water management.

The first aggregated accounts for the industry will be published in 2015 after steps were taken to align all companies' reporting periods. However, a preliminary assessment of available data from 2013 has shown that around 50% of water used in mines comes from onsite rainfall and run-off, and a third of the water is sourced from groundwater sources that are predominantly saline and therefore of limited use to other industries or irrigators. The analysis also showed that mines discharged only 3% of their water back into streams and rivers.

Water being sprayed on a mine haul road to reduce dust at a Hunter Valley mine.

11.2.1 Water balance modelling

A water balance model is an important tool for water surplus and deficit risk evaluation on all management timescales and provides data for producing water accounts. The tools and data supporting an operational site water balance model are shown in Figure 8.

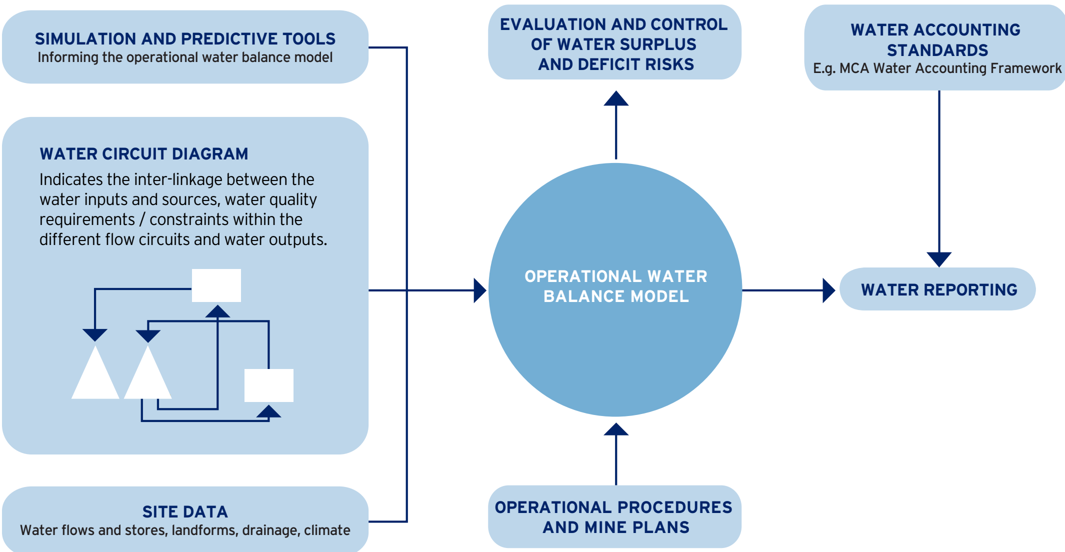
What is a water balance?

A water balance is simply a statement of the input and output of water volume across a defined system boundary, such as the lease boundary or a concentrator, in a defined period. If input is greater than output in that period, storage within the system increases; if input is greater than output, storage decreases. In simple mathematical form:

$$\Delta storage = input - output$$

Generally, the purpose of a water balance is to support decision-making or reporting by determining the quantity of water in a storage or moving between tasks or storages or by determining the conditions under which storage will exceed or fall below a design level.

Figure 8: General role of the operational site water balance model



The site water circuit diagram specifies the components of the mine water system. Various forms of water circuit diagrams are used, depending on the scale and resolution required. In many cases, some basic or conceptual conveyance and volumetric capacity diagrams are sufficient to outline the broad hydraulic processes between source, use, storage and discharge points. More detailed circuit diagrams are likely to be developed for site-specific infrastructure or controls, such as potable drinking water plans and processing plant and dewatering networks. Ideally, the diagram carries information on infrastructure, the hydraulic and capacity properties of components and the flows between them. It also includes interactions between the physical infrastructure and the landscape hydrological components that interact with it. Points of water input to and output from the site are indicated. These diagrams can become quickly obsolete and redundant owing to the dynamic nature of infrastructure, and their complexity and application should be based on their application and use. Disciplined document and version control is needed for all levels and scales of water circuit diagrams. Careful fit-for-purpose planning needs to be considered when developing the diagrams.

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 changes rarely, such as average monthly potential evaporation, and other data almost constantly, such as water levels in process ponds. Accurate and well-managed datasets provide the basis for robust and correct reporting and also ensure the timely interpretation of data to enable improvement and the identification of evolving trends and risks. It is also important to manage metadata (such as the changes made to bore casing height as the mine develops) and to store datasets that are no longer active (such as from exploration bores).[35]

The operational site water balance model may be supported by flow and storage data from a range of other models, such as models of the local groundwater system, seepage, rainfall run-off, tailings storage facilities and other site tasks.

The model may be used either to simulate the existing system or to predict the water balance under scenarios of future operating conditions (for example, under various climate scenarios). Furthermore, the water balance model may be used for multiple purposes, and more than one model with varying degrees of complexity may exist for an operation. To provide data to support water accounting, the mining operation may need a relatively simple water balance model that lumps together the water balance components into the definitions defined by the MCA Water Accounting Framework. On the other hand, to support the design and operation of infrastructure, explicit representation of relevant components are needed. The purpose of the water balance model also dictates the required level of accuracy and how often the water balance needs to be updated. Good practice is therefore to develop a water balance model that is fit for purpose and representative of current and predicted conditions.

Water balance modelling, like all numerical modelling, should be conducted following good practice modelling guidelines covering model selection, calibration, verification, sensitivity analysis, application and review.[36] For example, groundwater modelling should be carried out in accordance with the *Australian groundwater modelling guidelines* (NWC 2012).

35 Section 12 provides guidance on monitoring systems.

36 Discussed in Section 8.

11.2.2 Water accounting frameworks

Numerous frameworks aim to support good practice in water performance reporting. For example, the Global Reporting Initiative (GRI) is widely used for corporate-level water performance reporting and includes five metrics of water performance. The MCA's Water Accounting Framework (MCA 2014) represents good practice in mining. It was developed to produce accounts that can easily be aggregated to meet the GRI water reporting requirements, while also providing clear and transparent reports about site-level water input, outputs and efficiency.

The MCA Water Accounting Framework produces the following four reports:

- The *input–output statement* lists flows for all input and output categories for a defined reporting period, along with the change in storage. Each input and output includes its water quality category.
- The *statement of operational efficiencies* lists the total flows into the tasks, volume of reused water, reuse efficiency, volume of recycled water and recycling efficiency, with supporting definitions of those terms.
- The *accuracy statement* lists the percentage of flows that were measured or simulated and otherwise estimated.
- *Contextual information* ensures that numbers in the report are not divorced from the context in which the facility is operating. It gives information about the water resources of the region and the catchment in which the operation is located.

The development and testing of the MCA Water Accounting Framework between 2005 and 2009 was supported by a working group consisting of mine water managers and developers, as well as pilot testing, external review and the publication of a guidance manual. This ensured that the framework uses accounting definitions that are relevant and clear; can be applied practically after only modest training; and, as far as possible, is consistent with corporate and site reporting requirements.

Table 6 gives example of the water source and discharge definitions; the case study below shows the framework in use.

Table 6: Types and definitions of water sources and destinations used by the MCA Water Accounting Framework

SOURCE	DEFINITION	INPUT
Surface water	All water naturally open to the atmosphere, except for water in oceans, seas and estuaries.	Precipitation and run-off
		Rivers and creeks
		External surface water storages
Groundwater	Water beneath the Earth's surface that fills pores or cracks between porous media such as soil, rock, coal and sand, often forming aquifers. For accounting purposes, water that is entrained in ore can be considered as groundwater.	Aquifer interception (dewatering)
		Borefields
		Ore entrainment
Sea water	Water from oceans, seas and estuaries.	Estuary
		Sea/ocean
Third party	Water supplied by an entity external to the operational facility. Third-party water contains water from the other three sources. When the source is known, the physical source (surface water, groundwater, seawater) should prevail.	Contract/municipal
		Wastewater
Surface water	All water naturally open to the atmosphere, except for water from oceans, seas and estuaries.	Discharge
		Environmental flows
Groundwater	Water beneath the earth's surface that fills pores or cracks between porous media such as soil, rock, coal, and sand often forming aquifers.	Seepage
		Aquifer injection
Sea water	Water to oceans, seas and estuaries.	Estuary
		Sea/ocean
Third party	Water supplied to an entity external to the operational facility.	Third party
Other	Includes evaporation, entrainment, task loss and any other destination that is not covered by the other pathways.	Evaporation
		Entrained water in waste material (tailings, coarse rejects) and concentrate
		Task loss

Case study: The MCA Water Accounting Framework in use

Input–output statement for 1 July 2010 to 30 June 2011

		WATER QUALITY CATEGORIES (ML)[a]		
SOURCE	**INPUT**	**1**	**2**	**3**
Surface Water	Rivers and Creeks	685		
Groundwater	Entrainment		149	
Third-party Water	Contract/Municipal	1,169		
	Waste Water	157		
	Unknown	36		
TOTAL INPUTS: 2,196 ML		**2,047**	**149**	
DESTINATION	**OUTPUTS**	**1**	**2**	**3**
Surface Water	Discharge	82		
Other	Evaporation from stores and TSF	73		
	Evaporation from road	746		
	Evaporation from product and waste	419		
	Entrainment (water in waste and product streams)		793	
	Task loss		83	
TOTAL OUTPUTS: 2,196 ML		**1,320**	**876**	

[a] Water quality ranges from Category 1 (high-quality water) to Category 3 (low-quality water). low quality water (Category 3).

Statement of operational efficiencies

Total volume to tasks (ML/year)	5,579
Total volume of reused water (ML/year)	3,588
Reuse efficiency (%)	64
Total volume of recycled water (ML/year)	0
Recycling efficiency (%)	0

Accuracy statement

FLOW TYPES	% OF ALL FLOWS	CONFIDENCE (%)		
		HIGH	MEDIUM	LOW
Measured	20%	20%	0%	0%
Estimated	80%	7%	73%	0%
Simulated	0%	0%	0%	0%
Total		**27%**	**73%**	**0%**

Contextual statement

The reporting period was from the 1 July 2010 to 30 June 2011. This site is an open-pit copper mine with an associated leaching process, solvents extraction and electro-winning. The operation was in a desert region, so the site received very little rainfall. There was no long-term storage of water. Tasks were the waste rock dump, heap leaching pads, solvent extraction and electro-winning, campsite, plant use, dust suppression, and a small amount of other miscellaneous uses. Water was reclaimed from the waste rock dump, the heap leaching pads and the solvent extraction and electro-winning process. The unknown flow in the input–output statement was included to balance the account against known flows, indicating less than a 2% error in the account.

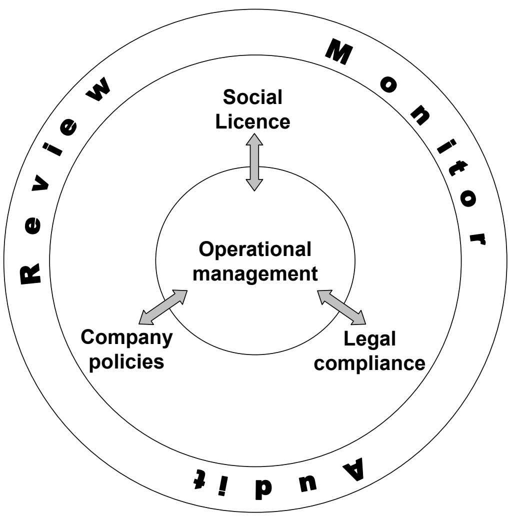
12.0 MONITOR, AUDIT AND REVIEW

Key messages

- Effective monitoring of performance and regular auditing and review processes at all stages of the mine life cycle will meet the goals set by the business case, manage risks and inform improvement opportunities.
- Formal documentation is an essential part of the improvement pathway, achieves legislative requirements and can provide transparency to interested community groups.
- An internal and external auditing process ensures that quality control standards are introduced and achieved and allows mining companies to maintain a line of sight on significant risks, particularly at the corporate level.

Monitoring, auditing and reviewing are the measurements and processes required to assess whether the management of the key operational and strategic risks is effective. Effectiveness must be assessed against the requirements set by the three areas of governance: corporate, government and community (Figure 9). The requirements from each of these areas should be embedded into the operational management tools and processes discussed in detail in Part IV. That is, monitoring (which includes reporting), auditing and reviewing must be able to assure the operation's water performance with reference to the planning tools and procedures outlined in Figure 7. Effective coupling between each of these processes is needed to achieve fit-for-purpose leading practice water management. The fundamental underpinning for such assurance is provided by physical monitoring of the water system on site and off site. This section focuses on this aspect.

Figure 9: Monitoring, auditing and reviewing support operational management through measurement and measurement evaluation



12.1 Physical system monitoring

12.1.1 Essential features of leading practice

The following aspects should be included for leading practice monitoring:

- A water monitoring scope for the mining project or operation should reflect the range of risk parameters and conditions that effectively inform business decision and improvement processes.
- Monitoring is typically viewed as a key stewardship activity that informs environmental and social performance through established targets and thresholds.
- Ongoing monitoring is a key activity and addresses technical uncertainty, supports preventive and mitigating controls, and facilitates the application of adaptive management techniques.
- Invest in feasible and practical systems with early-warning capability, including, where appropriate, online, real-time data uploads and time-integrated sampling systems.
- Extend the data capture and monitoring to include infrastructure performance, failures and maintenance frequencies.
- Manage metadata (such as changes to parameters as the mine develops) and store datasets that are no longer active (such as from exploration bores or from bores that have been buried under tailings dam walls.
- Apply appropriate quality assurance or quality control to and audit all procedures.
- Develop site-specific guideline water-quality trigger values consistent with the ANZECC–ARMCANZ (2000a) guidelines, rather than using default values.

12.1.2 Principal objectives

The principal objectives of water monitoring are to inform and optimise operational performance, to minimise impacts on the environment, water resource or community and, importantly, to address legislative requirements. This is achieved by monitoring a range of hydrological conditions, such as onsite water quality, the level and quantity of surface water and groundwater, and indirect conditions such as dust, pore pressures in pit slopes and ecological conditions and health. The appropriate monitoring networks and facilities to address these core requirements vary from site to site and potentially between different states. To achieve the best outcome from the monitoring, the maintenance and improvement processes need to be regularly reviewed and updated to ensure a fit-for-purpose application and to remove redundancy.

This section focuses on the monitoring of hydrological condition rather than infrastructure function and improvement. Monitoring requirements at various stages of the mine life cycle are shown in Table 7. The extent of monitoring needed to support the development and operation of the mine vary depending on state regulation. Western Australia's *Water in mining guideline* (DoW 2013) provides an example of regulatory requirements for the different stages of a mine approval.

12.1.3 Onsite and catchment-scale water monitoring

Monitoring program objectives must be conscious of scale, such as the onsite and offsite activities required to manage direct and indirect risks. Monitoring programs can meet multiple objectives for both production management (dewatering performance) and environmental compliance (stream water quality, groundwater quality), and any modification of one program must take into account the other program's objective. Coordinating the monitoring objectives through a central water management committee minimises duplication and streamlines the outcome.

Onsite issues largely relate to water (and constituent) activities as inflows into, around and out of the operation. The water management plan should be the reference point to outline and specify the requirements for onsite monitoring and demonstrate the links to regional or catchment-scale monitoring.

The priorities for metering and measurement are locations where:

- there are large fluxes of water
- water quality is significantly altered
- an operational task is sensitive to changes in quality, flow and level
- there is a hazard to safety or human or ecosystem health
- there is a risk of off-site movement of contaminants (such as a down-gradient groundwater bore).

The overarching requirements are to ensure that there is sufficient water for operations and to remove operational water constraints (such as dewatering or water inflow) 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 management and monitoring considerations and requirements, by phase of the mine life cycle

MINE LIFE CYCLE STAGE	MONITORING SCOPE	PRIMARY MONITORING PURPOSE	WATER-RELATED ACTIVITY
Exploration and planning	Baseline monitoring	Initial baseline development Natural variance monitoring Input to conceptual model	Environmental approvals Water supply options Preparation for sediment management
Development and expansion	Baseline monitoring Proactive monitoring	Improve baseline inventory Set reference sites Establish operational monitoring configurations Set early-warning monitoring facilities Establish third-party effects	Increasing hydrological knowledge Developing water management plans Preparing an environmental impact statement Setting operational production water targets Establishing environmental and management thresholds

MINE LIFE CYCLE STAGE	MONITORING SCOPE	PRIMARY MONITORING PURPOSE	WATER-RELATED ACTIVITY
Operations	Improvement monitoring Compliance monitoring	Operational performance monitoring review (pit slope depressurisation and environmental impact potentials) Preventive control monitoring (compare water-quality trends with baseline) Mitigating monitoring (review performance of remediation system) Baseline knowledge improvement Water balance model data requirements Closure preparation	Surplus discharge management Acid-rock drainage Tailings management Solid waste management Dewatering performance Water supply sustainability Environmental impact threshold Water and environmental licence compliance Groundwater-dependent ecosystem health and abundance (indirect)
Closure	Mitigating monitoring Recovery monitoring	Post-closure water compliance monitoring Adaptive management monitoring	Water levels, flow and quality Sediment monitoring Ecological health monitoring Pit lake recovery monitoring Acid rock drainage capture and treatment monitoring

Onsite water monitoring must provide feedback, in some cases in real time, to support the site operators in making timely and effective decisions about water management. This may require 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 and for operational uses should be determined and appropriate action responses (such as reducing or terminating discharge flow) should be linked to the thresholds. Real-time monitoring of wellfield pump performance and pipeline conditions ensures that emerging issues and maintenance requirements can be identified and rectified without interruption to the mine's operational water supply.

Where groundwater is likely to be affected 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. These are referred to as early-warning monitoring facilities. Management to minimise such impacts might be required, including the use of recovery or injection bores for treatment or reuse. Mitigation monitoring is therefore needed to measure this management performance and compliance.

Monitoring data is an input into the development and improvement of numerical models that can predict the likely range of changes associated with the onsite activity or remedial action. The data can also be used as an input to the development of a conceptual model long before there is sufficient data for a numerical model. Conversely, the optimised location and use of the monitoring facilities can be determined from running predictive scenarios with numerical models to identify where key uncertainty exists and monitoring data would strengthen the calibration and predictive output (NWC 2012).

Where appropriate, shared monitoring can lead to reduced costs and also allow the mining company to achieve benefits from community engagement. Where multiple mining operators exist within a catchment, a monitoring system that addresses potential cumulative effects and impacts is ideal but not always practicable, as data can provide commercial advantages. The collection, storage, use and sharing of data may need to be managed through robust governance frameworks and agreements to provide transparency or to protect commercially sensitive information.

12.1.4 Water quality and environmental monitoring

The guidelines for receiving water quality are defined at the federal level (ANZECC–ARMCANZ 2000a) and enforced by state regulatory agencies. Batley et al. (2003) is a guide to their application in the minerals industry. The most stringent guidelines, which normally apply, are those for the protection of aquatic ecosystems, as distinct from those for other values, such as recreational water or water for agricultural use.

The guideline values that apply in a given situation depend on whether the receiving waters are of high conservation value (99% ecosystem protection), slightly/moderately disturbed (95% ecosystem protection), or highly disturbed (80% or less ecosystem protection). This level of protection is determined in consultation with the regulator and other stakeholders. The guideline trigger values are not concentration limits; rather, they are 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.

Leading practice operators routinely monitor the quality of onsite water and of the waters receiving their discharges or run-off, both upstream and downstream of their operations, as well as in waters in nearby reference catchments 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.

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, so that appropriate, sensitive parameters and endpoints can be selected to enable the detection of underlying trends before impacts occur. Monitoring that is able to detect changes only after an impact has occurred cannot be used to manage systems to prevent impacts and minimise liabilities. A common misconception is that monitoring for compliance is sufficient to manage discharges. If the first measurement of change is of a change 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. Measurements of total or total-dissolved concentrations of contaminants can substantially overestimate the bioavailable 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).

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 or trigger concentrations are exceeded.

Details of how to develop and run a monitoring program that is consistent with international best practice are in the *Australian guidelines for water quality monitoring and reporting* (ANZECC–ARMCANZ 2000b). The key elements are the sampling locations and the frequency and the composition of the suite of measurements. In particular, measurement sensitivity and the 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 when an identified trend away from baseline occurs or when an agreed threshold or trigger investigation level is reached. The triggers should be conservative or precautionary, such that they are within natural baseline ranges or materially below the values at which unacceptable ecological damage will occur.

Appropriate quality assurance and quality control (QA/QC) are essential in both sampling and analysis. Ideally, chemical analyses for key contaminants should be done by a laboratory accredited by 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 the protection of high-value aquatic ecosystems (99% protection) or for slightly to moderately disturbed aquatic ecosystems for some parameters (95% protection). There must also be adequate traceability of derived results to primary data, and 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, some commercial ecotoxicology testing laboratories can measure the toxicity of mine effluents using a suite of test organisms, and some biological consultants can provide local assessments using appropriate ecosystem monitoring tools. Guidance on field monitoring of biological community abundance and toxicity is in Batley et al. (2003).

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

12.2 Performance assessment and reporting

Performance is assessed by comparing data from the site, from either 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 is an ongoing process and includes reporting to meet both internal and external obligations. Internal reporting assesses the performance of management systems and the need for modifications, including possible the treatment of discharges. External reporting to stakeholders, including regulators, demonstrates the operation’s impact on the external receiving environment or its compliance with licence conditions.

At least on an annual basis, the water management monitoring and reporting system should be reviewed through analysis of data records, incidents or issues to determine whether the system is operating effectively and whether the procedures and monitoring programs are adequate. Data interpretation and assessment are a key element or step of the adaptive management and improvement cycle outlined in Figure 5.

Asset monitoring data obtained from key water infrastructure should be regularly reviewed to assess performance and operational activity. The review can lead to significant improvements and cost savings. This may include pump or pipeline hydraulic performance, and the interpretation of monitoring data will enable optimised engineering and improved operational configurations.

Case study: Managing environmental information at Anglo American

Anglo American Coal in Australia has six coal operations in Queensland and New South Wales, each managing large amounts of environmental data. In 2012, Anglo American selected a software package called EnviroSys to collect all environmental data and produce reports to meet internal and external requirements. Data collected in EnviroSys includes:

- all data from the automated monitoring network, automatically imported into EnviroSys (weather, creek flows, water quality)
- all results from third-party laboratory analyses of samples (water and dust), automatically imported into EnviroSys
- all data required for corporate environmental reporting into Enablon, which is a system to manage health, safety and environmental information (air emissions, waste, climate change, energy).

Water balance data is entered in accordance with the MCA Water Accounting Framework and covers inputs, outputs, task-level demands and volumes of water stored on site. This ensures consistency across operations for water reporting (for example, monthly site water balance reporting).

Anglo American in Australia spends more than $2 million per year on water-quality analysis performed by third-party suppliers. Data was previously supplied as separate spreadsheets, which meant that analysis was very time-consuming and opportunities for key improvements were missed. With EnviroSys, all laboratory data is now easily interrogated, compiled and analysed. At each Queensland operation, EnviroSys is used to report on the receiving environment monitoring program and has demonstrated that the operations are not affecting the receiving environment. The data can also be directly submitted to the regulator's own database (WaTERS).

The number of environmental obligations that each operation must comply with has steadily increased in the past few years. In Queensland, sites comply with 128 conditions, and other commitments arise from plans of operations, annual returns, water licences, water diversions, audits and instrumentation calibration. In New South Wales, conditions are similar, with more stringent guidelines for noise and dust management. Anglo American implemented an obligation module in EnviroSys to assist with managing the expanding number of environmental obligations. The advantage of using EnviroSys for obligation management is that both the obligations and the data that prove compliance with the obligations are held in the same system.

All Anglo American operations in Australia are now using EnviroSys to manage environmental data and to track and manage their environmental obligations.

Monitoring location on German Creek downstream of the Capcoal mining complex operated by Anglo American in Central Queensland.

12.3 Auditing

Internal and external auditing are performed for different purposes. Internal auditing is essential to determine whether risks are controlled, whether monitoring and reporting systems are operating according to design and whether business objectives are being achieved. External monitoring is to demonstrate that regulatory licence conditions or stakeholder expectations are being met.

Both internal and external auditing should assess adherence to appropriate QA/QC, the training and capability of monitoring and operational staff, and the usefulness and reliability of any conclusions drawn from the data in relation to the identification of trends, causes and impacts. Auditing should also assess the safety of all field and laboratory operations. Internal audits are typically more frequent than external audits, but the extent of auditing depends on the range and severity of the risks, monitoring objectives and the mining company's overall governance structure. Significant or material water risks may be subject to a more formal process of auditing, in which controls and control owners report on the risk management process and auditing is completed in relation to progress against the risk action items.

Water-quality monitoring should be a component of an overall environmental management system that has appropriate quality assurance and auditing that is consistent with ISO 14000, the International Standards Organization's family of standards for environmental management. For ISO 14000, an internal system is required that will ensure that the external review or audit is passed. A critical tool is an up-to-date site risk register, together with a complementary action or project implementation plan, including responsibilities, costs, times and details of staff training. The approach is designed to minimise risks and be a blueprint for continuing improvement.

REFERENCES

ABS (Australian Bureau of Statistics) (2013). *Water account Australia 2012–13*, ABS catalogue no. 4610.0, ABS, Canberra.

ACIL Tasman (2007). *Water reform and industry: implications of recent water initiatives for the minerals, petroleum, energy, pulp and paper industries*, report prepared for the Department of Industry, Tourism and Resources, http://archive.nwc.gov.au/__data/assets/pdf_file/0011/11513/Water_Reform_and_Industry.pdf.

ANZECC–ARMCANZ (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand) (1996). *National principles for the provision of water for ecosystems*, ANZECC & ARMCANZ, Canberra, http://www.environment.gov.au/system/files/resources/051a0db6-8f18-4999-96ee-4b24d46d2515/files/water-provision.pdf.

ANZECC–ARMCANZ (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand) (2000a). *Australian and New Zealand guidelines for fresh and marine water quality*, National Water Quality Management Strategy paper no. 4, ANZECC & ARMCANZ, Canberra.

ANZECC–ARMCANZ (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand) (2000b). *Australian guidelines for water quality monitoring and reporting*, National Water Quality Management Strategy paper no. 7, ANZECC & ARMCANZ, Canberra.

Barber, M, Jackson, S (2011). *Water and Indigenous people in the Pilbara, Western Australia: a preliminary study*, Water for a Healthy Country Flagship, CSIRO.

Batley, GE, Humphrey, CL, Apte, SC, Stauber, JL (2003). *A practical guide to the application of the ANZECC–ARMCANZ water quality guidelines for the mining industry*, Australian Centre for Mining Environmental Research, Brisbane, Queensland.

BoM (Bureau of Meteorology) (2012). *The Groundwater Dependent Ecosystem Atlas*, http://www.bom.gov.au/water/groundwater/gde.

Byrne, G (2013). 'Long-term water management: the forgotten legacy of mine closure', *Proceedings of AusIMM Water in Mining conference 2013* (pp. 163–168), Brisbane, November 2013.

CDP (2013). *CDP global water report 2013*, https://www.cdp.net/CDPResults/CDP-Global-Water-Report-2013.pdf.

CDP (2014). *CDP global water report 2014*, http://www.cdp.net/CDPResults/CDP-Global-Water-Report-2014.pdf.

COAG (Council of Australian Governments) (1994). *Council of Australian Governments communiqué*, 25 February, http://archive.coag.gov.au/coag_meeting_outcomes/1994-02-25/index.cfm.

CSIRO (2009). *Australian Soil and Land Survey field handbook*, 3rd edition, National Committee on Soil and Terrain, CSIRO Publishing, Collingwood, Victoria.

DECC (NSW Department of Environment and Climate Change) (2008). *Managing urban stormwater: Soil and construction, volume 2E, Mines and quarries*, DECC, Sydney.

DEHP (Queensland Department of Environment and Heritage Protection) (2013). *Monitoring and sampling manual 2009*, version 2, DEHP, Brisbane.

Delzoppo, L (2011). 'The management of mine water quality in the Fitzroy River Basin', presentation by Lindsay Delzoppo, General Manager, Operations, Department of Environment and Resource Management, to the AWA Technical Seminar Series, 13 April 2011, Greek Club, South Brisbane, Queensland.

DIIS (Department of Industry, Innovation and Science) (2016). Leading Practice Sustainable Development handbooks series, DIIS, Canberra, http://www.industry.gov.au/resource/Programs/LPSD/Pages/LPSDhandbooks.aspx.

DNRM (Queensland Department of Natural Resources and Mines) (2014). *Guideline: works that interfere with water in a watercourse—watercourse diversions*, DNRP, Brisbane.

Dobbs, R, Davies, PM (2009). *Long term ecological research on a Pilbara River system: analysis of long term Robe River aquatic monitoring dataset,* report 11/05, Centre of Excellence in Natural Resource Management, University of Western Australia, http://www.water.wa.gov.au/PublicationStore/first/96676.pdf.

DoW (Western Australian Department of Water) (2013). *Water in mining guideline*, Water Licensing Delivery Series report no. 12, DoW, Perth, https://www.water.wa.gov.au/__data/assets/pdf_file/0019/1819/105195.pdf.

DoW (Western Australian Department of Water) (2014). *Annual report 2013–14*, http://www.water.wa.gov.au/107920.pdf?id=417.

DRET (Department of Resources, Energy and Tourism) (2009). Airborne contaminants, noise and vibration, DRET, Canberra, http://www.industry.gov.au/resource/Programs/LPSD/Pages/LPSDhandbooks.aspx.

DTMR (Queensland Department of Transport and Main Roads) (2010). *Road drainage design manual*, 2nd edition, March, DTMR, Brisbane.

Environment Australia (2000). *Freshwater related environmental management principles and guidelines*, http://www.environment.gov.au/system/files/resources/ecc57dce-6832-40df-a321-5a3857c69a72/files/principles.pdf.

Evans, R, Moran, CJ, Brereton, D (2006). 'Beyond NPV: a review of valuation methodologies and their applicability to water in mining', *Proceedings of AusIMM Water in Mining Conference 2006* (pp.97–104), Brisbane, November 2006.

Hoff, H (2011). 'Understanding the nexus', background paper for Bonn 2011 Conference: The Water, Energy and Food Security Nexus, Stockholm Environment Institute, Stockholm.

ICMM (International Council on Mining and Metals) (2014). *Water Stewardship Framework*, ICMM, London, http://www.icmm.com/water.

ICMM (International Council on Mining and Metals) (2015). *A practical guide to catchment-based water management for the mining and metals industry*, ICMM, London, http://www.icmm.com/document/8329.

IEAust (Institution of Engineers Australia) (1987–1999). *Australian rainfall and runoff*, 3rd edition, Engineers Australia, Barton, ACT.

IEAust (Institution of Engineers Australia) (no date). *Best practice erosion and sediment control guidelines*, IEAust, http://www.austieca.com.au/publications/best-practice-erosion-and-sediment-control-bpesc-document.

IECA (International Erosion Control Association) (2008). *Best practice erosion and sediment control*, IECA, Picton, NSW.

IMC (Imperial Metal Corporation) (2015). Press release regarding the report by the Mount Polley Independent Expert Engineering Investigation and Review Panel, http://www.imperialmetals.com/s/News_2015.asp?ReportID=694739.

MCA (Minerals Council of Australia) (1997). *Mine site water management handbook*, MCA, http://www.minerals.org.au/file_upload/files/resources/environment/Minesite_Water_Management_Handbook.pdf.

MCA (Minerals Council of Australia) (2014). *Water accounting framework for the minerals industry*, version 1.3, http://www.minerals.org.au/file_upload/files/resources/water_accounting/WAF_UserGuide_v1.3_%28Jan_2014%29.pdf.

MCA (Minerals Council of Australia) (2015). *Water accounting*, MCA, http://www.minerals.org.au/focus/sustainable_development/water_accounting.

MDBA (Murray–Darling Basin Authority) (2012). *Basin Plan*, MDBA, http://www.mdba.gov.au/sites/default/files/Basin-Plan/Basin-Plan-Nov2012.pdf.

Morison, K (2014). 'The impact of water trading on agricultural productivity', presentation to the Australian Water Association National Water Policy Summit.

NHMRC (National Health and Medical Research Council) (2011), *Australian drinking water guidelines*, updated February 2016, NHMRC, Canberra, https://www.nhmrc.gov.au/_files_nhmrc/file/publications/nhmrc_adwg_6_february_2016.pdf.

NSW EPA (NSW Environment Protection Authority) (2013). *Review of the Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002: discussion paper*, http://www.epa.nsw.gov.au/resources/licensing/hrsts/13771hrstsdp.pdf.

NSW EPA (NSW Environment Protection Authority) (2014). 'Pollution incidents cost Big Island Mining close to $200,000', media release, 1 September, NSW EPA, Sydney, http://www.epa.nsw.gov.au/epamedia/EPAMedia14090101.htm.

NUDLC (National Uniform Drillers Licensing Committee) (2012). *Minimum construction requirements for water bores in Australia*, 3rd edition, February, NUDLC.

NWC (National Water Commission) (2004). *Intergovernmental agreement on a National Water Initiative*, NWC, Canberra, http://www.nwc.gov.au/nwi.

NWC (National Water Commission) (2012). *Australian groundwater modelling guidelines*, Waterlines report no. 82, June, NWC, Canberra, http://archive.nwc.gov.au/library/waterlines/82.

NWC (National Water Commission) (2014a). *Australia's water blueprint: national reform assessment 2014*, NWC, Canberra, http://www.nwc.gov.au/publications/topic/assessments/australias-water-blueprint-national-reform-assessment-2014.

NWC (National Water Commission) (2014b). *Water for mining and unconventional gas under the National Water Initiative*, NWC, Canberra, http://www.nwc.gov.au/publications/topic/water-planning/water-for-mining-and-unconventional-gas-under-the-national-water-initiative.

OOW (NSW Office of Water) (2014). *Groundwater monitoring and modelling plans: information for prospective mining and petroleum exploration activities*, February, OOW, Sydney, http://www.water.nsw.gov.au/__data/assets/pdf_file/0010/547543/law_key_aquifer_interference_groundwater-monitoring-modelling-project-info-mining.pdf.

Pacific Institute (no date). Corporate water stewardship, Pacific Institute, Oakland, California, http://pacinst.org/issues/corporate-water-stewardship/.

Rea, I, Monaghan, D (2009). 'Dewatering bore pumps: reducing costs and emissions by maximising pumping efficiencies over time', *Proceedings of the Water in Mining Conference 2009* (pp. 205–210), Perth, September.

WA EPA (Western Australian Environment Protection Authority) (2013). *Environmental assessment guideline for consideration of subterranean fauna in environmental impact assessment in Western Australia*, EPA, Perth, http://edit.epa.wa.gov.au/EPADocLib/EAG12%20Subterranean%20fauna.pdf.

WEF (World Economic Forum) (2015). *Global risks 2015: insight report*, 10th edition, WEF, http://www3.weforum.org/docs/WEF_Global_Risks_2015_Report15.pdf.

Woodley, A, Danoucaras, AN, McCombe, C, Kunz, NC, Collins, N (2013). 'A robust methodological approach for mine site water accounting', *Proceedings of AusIMM Water In Mining conference 2013* (pp. 267–272), Brisbane, November.

Younger, PL, Robins, NS (2002). *Mine water hydrogeology and geochemistry*, Geological Society, London, Special Publications.

Younger, PL, Banwart, SA, Hedin, RS (2002). *Mine water: hydrology, pollution, remediation*, Kluwer Academic Publishers, Dordrecht, ISBN 1-4020-0137-1.

SOCIAL
ECONOMIC
ENVIRONMENTAL

Leading Practice Sustainable Development Program for the Mining Industry