

# Beyond NPV — A Review of Valuation Methodologies and Their Applicability to Water in Mining

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## ABSTRACT

In this era of rising focus on the social and environmental costs and benefits of mining operations, the valuation methodologies used to assess such impacts become increasingly important. Within an industry dominated by an engineering culture that places emphasis on net present value (NPV) calculations using high discount rates, difficulties often arise when attempting to justify projects with longer-term, harder to quantify benefits. This is particularly so when these benefits fall in the social and environmental domains and involve other stakeholders. In this paper, we summarise the results of a recent literature review on this subject, which focused on the valuation of 'Beyond Compliance' initiatives in the mining sector. We discuss a range of approaches including the quantification of hidden internal costs, financial methods of incorporating risk into calculations, the integration of quantitative and qualitative information, and also the valuation of 'externalities' or costs and benefits borne by others. We then use a series of examples relating to the management of water in the minerals industry to illustrate how some of these approaches could be applied. There are high-level commitments from both individual companies and groups such as the ICMM to incorporate sustainable development criteria into decision-making processes within the industry. We conclude the paper by arguing that, to meet these commitments, there is a need for the industry to adopt a broader range of valuation methodologies than appears to be the case at present.

## INTRODUCTION

Value is a difficult term, carrying with it a range of meanings depending on context and audience. The value of a mine is usually expressed within the industry in financial terms, yet few organisational 'Values' statements from the sector refer to financial outcomes, focusing instead on behavioural standards. Other stakeholders refer to environmental values threatened by mining operations. Few of these interpretations of value occur in the same documents or conversations.

The engagement of the minerals industry with the sustainable development agenda over the last decade (for example through the Mining, Minerals and Sustainable Development or MMSD project) has resulted in an increasing focus on the impacts (both positive and negative) of the industry's activities on a broad range of stakeholders. Gibson (2001) identifies as a trend:

*... an expansion of central concern from avoidance of significant adverse effects to expectation of positive contribution to the achievement of sustainability objectives.*

Companies are committing themselves to a range of initiatives under the sustainability banner which go beyond what is required by legislation, approaches described by a number of authors (eg Prakash, 2000; Gunningham, 2002) as 'Beyond Compliance'.

Such initiatives are designed to realise the 'positive contributions' referred to above. This has sparked much debate about 'Business Case' arguments, and an associated exploration of valuation techniques, which can be applied to benefits and costs experienced by both companies and other stakeholders. While net present value calculations based on discounted cash flows remain the mainstay of financial assessments, recent literature inspired by the sustainable development debate has explored extensions and alternatives to this approach. Issues of particular focus have been the appropriateness of discount rates and methods of incorporating risk and uncertainty (particularly in the environmental and social domains) into such calculations.

Access to fresh water represents an essential human need. Water is also fundamental to other ecosystem services required to sustain human life, and both the quantity and quality of water resources can be linked to financial, social and environmental values. Water is, therefore, understandably often viewed differently to other resources by society. It is high on the political agendas of all levels of government including the United Nations, and was recognised as a key theme in the MMSD project, with mines operating in the driest and the wettest regions on the planet. While not extracting as large a quantity of water as the agricultural sector in most parts of the world, individual mines are often large consumers in their local context, and their impacts in many aspects can be significant. Mining companies compete for water within a range of market and non-market jurisdictions. Water use in many processing activities results in bodies of contaminated water which, if incorrectly managed, pose risks for downstream values. Mining is often responsible for developing water infrastructure used by other industries and communities. Potential impacts of mining operations on both the quantity and quality of surface and groundwater resources are increasingly being raised as concerns by local communities, and in several cases have been the principal reason why some projects have not gone ahead. In other cases such concerns have driven significant changes in site water management practices (eg Merritt, 2006).

The intersection of these two themes of valuation and water therefore represents one of the most pressing and also most challenging areas within the sustainability framework for the minerals industry to explore. This paper starts with a description of the general literature on valuation approaches, including an exploration of water valuation within several categories. It then reviews the use of frameworks, and considers some examples from the minerals industry to illustrate situations in which certain valuation methodologies might be employed. Finally, some suggestions for further exploration and development of these ideas are presented.

## VALUATION LITERATURE

### Internal financial analysis

Organisations typically apply a range of financial techniques focusing on capital requirements and cash flows over time to evaluate projects or options. Within the mining industry the starting point is usually a net present value or NPV analysis. There is a range of literature which seeks to provide an overview of how such internal financial analysis can be used to assess projects or initiatives which deliver benefits in areas such as the

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environment or the health and safety of a workforce and/or the wider community. Reed (2001) discusses various approaches to calculate a business case, focusing particularly on newer methodologies such as real options analysis. The US EPA's *Introduction to Environmental Accounting* (1995) is one of the clearest summaries of the area, and also provides a useful glossary. Two main themes emerge from this literature: firstly, more detailed consideration of hidden and indirect costs is required to fully evaluate proposals; and secondly, risk and uncertainty associated with all aspects of the decision must be properly considered.

### *Detailed direct and indirect cost analysis*

Various sources have emphasised the need to capture all indirect and 'hidden' costs associated with different options (including the 'do nothing' option). At present, this information can be lost in overhead accounts. This literature argues that detailed cash flow analysis including all such elements will often result in apparently uneconomic projects becoming viable. Much of this literature refers back to the paper by Porter and van der Linde (1995), which emphasises the win/win nature of environmental initiatives such as eco-efficiency opportunities.

As an example, work on the hidden costs of safety incidents has been undertaken by academics (eg Rikhardsson, 2004) and the business sector (eg Dupont Safety Yardstick accessed at <http://www.dupont.com/safety/en/forms/safety-yardstick.shtml>). The latter work is based on US statistics and provides an estimate of average costs per lost time injury incidence.

With utilities such as energy or water, which are ubiquitous across processes within any large minerals project, there can be a tendency for the costs involved to be absorbed at a high level as overheads and not linked to specific processes. With water, this is particularly so where the price of supply has been traditionally low, resulting in the view of water within many organisations and communities as a 'free' resource. The default cost used in any analysis of alternatives that involve changes in water flows then becomes the purchase price, which may not accurately reflect the real costs involved. There is a link between the use of water and energy costs – in many cases, the cost of pumping water for supply and disposal, and as a medium for transporting material within process plants, will far outweigh the cost of purchase.

Another factor to be considered in this context is the opportunity cost associated with water use. Highlighted by Hernandez *et al* (2005) in the context of water reuse projects, the emergence of water markets in many parts of Australia provides additional incentives for projects which reduce consumption, since unused water allocations may be used to realise additional value.

### *Financial modelling of risk and contingencies*

The second key theme within the literature on internal financial analysis explores methodologies for attaching financial value to uncertain future events or contingencies. The same project undertaken by the US EPA provided a comprehensive list of techniques in this area, illustrated with examples from a wide range of companies. Approaches range from simple calculations of 'Expected Value' to more complex methodologies such as 'Monte Carlo analysis', and usually aim to combine the analysis results with a conventional NPV approach.

Recent developments have seen the use of financial value at risk (VaR) methodologies adopted from the share markets – for example, Fang, Ford and Mannan (2004) describe the combination of risk assessment and VaR methods in evaluating process safety. Bowden, Lane and Martin (2001) describe a methodology developed and deployed by a consultancy to explore the cost of potential risks in a variety of ways – case studies include the evaluation of options for managing riverine tailings issues at Ok Tedi.

Another recent approach to uncertainty involves 'real options', a methodology which attaches a financial value to the ownership of an option to do something in the future. Real options analysis emerged from financial market theory as a new approach to valuation involving real assets in situations which include elements of flexibility and uncertainty. It has been applied to a broad range of issues including corporate approaches to environmental problems, although its complexity has resulted in limited acceptance to date. Figge (2005) provides a non-mathematical description of the potential role of option analysis in environmental management.

In the water domain, there are several examples of the application of the real options methodology to issues of water supply. Gerrans (1999) uses it to assess the combination of alternatives under consideration to provide secure water supplies for Perth; Ramirez (2002) applies it to the evaluation of water supply options in Bogotá, Colombia. Both authors find that conventional NPV techniques do not adequately cope with the uncertainty of the environments involved.

### **External economic impacts and externalities**

Internal financial analysis focuses on the benefits and costs to a single organisation. However, decisions regarding water can be associated with significant economic impacts on other parties and organisations, as well as non-financial social and environmental impacts.

#### *Direct economic impacts*

Economic impacts to other parties in a market can be modelled at a high level using input-output analysis, which usually focuses at a regional and sector level. More commonly at a project level, for example in public project approval processes, a tool such as cost benefit analysis (CBA) (eg Hansjurgens, 2004) can be used to assess the flows of benefits and costs to various agents and stakeholders.

Batten (in press) provides a useful overview of a range of economic frameworks applied to the valuation of water. He identifies difficulties with valuing water as an ordinary economic good, associated with its role as part of a complex system, the lack of effective water markets and various characteristics including the fact that it is mostly non-substitutable. He then goes on to highlight a range of economic frameworks starting with conventional cost-benefit analysis, and also including input-output analysis, which facilitate the calculation of water use intensities, ie how much water is embodied in one dollar's worth of product. Of particular interest is an extension to cost-benefit analysis developed by researchers at Delft (described by Seyam, Hoekstra and Savenje, 2003): water value flow analysis recognises that value from any one drop of water can be realised at various stages through the hydrological cycle, and seeks to identify the downstream economic values and combine them with the direct value at any point in the cycle.

Batten identifies several serious deficiencies with pure economic frameworks for the valuation of water, noting their short-sightedness and difficulties in representing complex and dynamic systems. The challenge of extending them to include social and environmental values is also emphasised.

#### *Methodologies for costing externalities*

In the case of CBA, the approach may extend to attaching financial value to externalities, or impacts (positive or negative) that are not captured by existing markets. Economists discuss externalities in the context of market failures (see Common and Stagl, 2005, p 327), since no mechanism exists to formally attach a value to the effect in question. One of the principles enshrined in the UN's Rio Declaration (1992) was that 'National authorities

should endeavour to promote the internalisation of environmental costs'. Political responses have included establishing markets for negative externalities such as sulfur dioxide emissions in the USA, and more recently various initiatives involving trading of carbon dioxide emissions. Understanding and valuing external economic impacts and externalities associated with water is clearly an important part of any valuation framework.

Recent years have seen increasing discussion of non-market valuation approaches in the environmental or ecological economics literature. There is a large literature which describes non-market methods of establishing consumers 'willingness to pay' (WTP) via expressed or revealed preference techniques, eg contingent valuation techniques, hedonic pricing. Recent summaries of these methods can be found in Common and Stagl (2005) and Bennett (2005). There are also increasing numbers of case studies in a range of applications. Non-market valuation approaches have also been applied to issues of human health and safety. Calculations of such indicators as the statistical value of a human life can be controversial, but are nevertheless used by government authorities in the context of allocating resources to health initiatives.

The application of environmental externality techniques to the mineral industry context has been the subject of some discussion and criticism. Humphreys (2000) uses the example of studies carried out to establish a tax on aggregate products in the UK to argue strongly that such techniques need to reflect individual context and can be counter-productive. He maintains that political and social methods of resolving perceptions of value in such circumstances are more appropriate. Damigos (2006) offers three examples from the minerals sector which apply a range of methodologies to the cases of two new mining proposals and one abandoned mine clean-up operation. Applications of these techniques from within the mining context appear to be more limited than in other sectors.

For the reasons outlined in the introduction, water is associated with many, easily-recognised externalities. It has, therefore, been associated with most of the possible techniques found in the literature. Examples include contingent valuation described by Wattage and Soussan (2003) as part of an extended CBA carried out on water project development in Bangladesh; Choice Modelling (CM) used by Blamey, Gordon and Chapman (1999) to assess future water supply options for the Australian Capital Territory. Van Bueren and MacDonald (2004) provide a summary of the complexities involved with water-related externalities, illustrating this with a case study of environmental flows in the Murray.

### **Full cost accounting**

A stream of accounting research has focused on the practice of public reporting of externalities (in addition to internal environmental costs and benefits) in corporate accounts. Bebbington *et al* (2001) provide a recent overview of this area, including a study of five organisations that followed this approach. One UN report (UNCTAD, 2003) highlights this area as one in which little progress has been made by any industry sector (including the mining industry) since commitments made at the UN Rio 'Earth Summit'.

Additional literature under this heading focuses on the use of such valuation approaches to assessing specific projects or operations, often described as sustainability assessments. For example, Bebbington (2004) describes a modelling approach developed in conjunction with BP (SAM or the Sustainability Assessment Model), which sought to assign monetary values to social, environmental, resource and economic flows arising from oil and gas developments. This is one of several examples used in the broader overview compiled by Forum for the Future (2003).

### **Non-financial integrating frameworks**

A number of approaches and frameworks exist which seek to combine internal and external values, often in the context of making decisions regarding resource allocation or project approvals. While much attention has focused on methods of converting all costs and benefits including externalities into financial terms using tools such as CBA, some have argued that it is neither practical nor desirable to express all values in this way. Comparisons of financial and non-financial methodologies have been carried out by several authors (eg Hansjurgens, 2004; Phelan, 1997). Critics of the explicit financial approach have provided reviews of alternative methods of assigning value, along with some discussion on the suitability or otherwise of single number valuation indices (monetary or otherwise). A recent overview of alternative approaches is provided by Spash, Getzner and Stagl (2005). Two methods of evaluating financial and non-financial impacts at the same time include risk assessment and multi-criteria decision analysis (MCDA).

### **Risk assessment**

Risk assessment encompasses various methodologies which seek to combine the valuation of negative consequences in a number of specified impact areas with the likelihood of such events occurring. Qualitative risk assessment attaches value through the use of descriptive scales, while quantitative approaches seek to use more explicit measures. Some literature has focused on the definition and interpretation of 'value' in risk assessment processes including in the environmental area, eg Gregory, Brown and Knetsch, 1996; Fischhoff, 1996.

### **Multi-criteria decision analysis (MCDA)**

MCDA techniques represent a formal mathematical approach to integration of values using a range of criteria and value functions, usually (but not always) producing a single index for each alternative considered. Such techniques involve the weighting or definition of a more complex value function for each criterion under consideration. There is extensive literature about their application in public decision-making processes (see Hobbs and Meier, 2000 for examples relating to energy decisions), with some discussion on methods for investigating and resolving variations in value between different stakeholders. A recent overview of the application of multi-criteria approaches in the environmental arena is provided by de Montis *et al* (2005).

MCDA has also been applied to a range of decisions in other water management contexts. For example, Robinson (2002) outlines its use to assist the evaluation of an emerging groundwater problem involving a number of stakeholders in a catchment area in North Queensland. De Marchi (2000) describes another multiple stakeholder process to assess policy development associated with the under-exploitation of water resources at Troina, Sicily.

### **Summary**

The literature confirms that there is no shortage of valuation methodologies available to explore impacts both within and beyond the boundary of any given operation. These range from simple extensions of conventional cash flow analysis to account for hidden costs and overheads, more sophisticated methods of accounting for uncertainty, through to the valuation of external impacts and the application of integrative approaches such as MCDA. These methodologies are increasingly being applied to define value in decision-making contexts.

It is also apparent that there is no generally-accepted valuation framework that can be readily deployed to integrate different types of value. There are clearly attempts to bridge disciplinary divides in approaching the issue, but the challenge remains.

## APPLICATIONS FOR WATER IN MINING

The themes identified in the previous section have clear resonance with a range of issues encountered by mining operations when considering the management of water. Following on from the literature outlined in the first part of this paper, this section aims to provide examples of how some valuation methodologies might be applied to current issues in the minerals industry. It also considers a case study of one particular valuation process and its context, to illustrate both the possibilities and the difficulties involved. Neither section is exhaustive; the aim is to provide a range of examples that illustrate application of alternative valuation processes.

### Examples of applications

#### *Increased focus on understanding hidden costs*

The context for water use in mineral operations varies considerably. Within Australia, there are a number of individual operations and also mining regions which rely on water provided through extensive pipeline networks, while others rely on surface or groundwater resources located closer to the operation. The costs of supplying this water to mines and concentrators can be significant, and yet is not always understood by those in charge of its use (particularly if the infrastructure is owned and operated by the mining company involved). Conventional cash flow analyses can reveal useful information when such costs are included and thought is given as to full life cycle costs. Examples include the following:

- Accounting for water losses – significant seepage and evaporation losses of water can occur from freshwater storages on mine sites, when that water has been pumped in some cases hundreds of kilometres from source thereby incurring considerable energy cost.
- Management of ‘worked’ water – the amount of ‘dirty’ or ‘worked’ water in storage on mine sites is linked to the volume imported, and can incur substantial costs associated with pumping, monitoring and possible discharge operations. Seepage and evaporation losses from these storages can also represent missed opportunities in terms of availability of water for recycling.
- Substitution opportunities – adoption of a ‘fit for purpose’ policy at one mine site has seen a move from expensive, imported water for equipment wash-down in a once-through cycle to the recycling of relatively clean water from a nearby mine water storage (Evans and Roe, 2003).
- Remediation of tailings storage facilities – management of water and recycling strategies plays a key role in the eventual costs of remediating tailings storage areas and dams. The relatively long lifespan of such facilities when coupled with high discount rates usually applied to discounted cash flows tends to minimise the importance of such costs. However, the trend towards fuller accounting for future liabilities has seen an increased focus in this area in recent years.

#### *Contingencies*

Risk and uncertainty concerning future outcomes is often a primary focus for many operators and stakeholders when considering mining operations. Possible supply restrictions have been the focus of much work in the prevailing drought conditions affecting much of eastern Australia. At the other end of the spectrum, all operations need to address flood events, which can interact with operations in a number of ways:

- Supply contingencies – Norgate and Lovel (2006) highlight several examples where mineral operations have undertaken projects to address concerns regarding supply contingencies,

where the issue is the cost of not having enough water to run production processes.

- Seawater cooling – many mineral processing operations along the coast have evaluated the prospect of using seawater to provide a more reliable supply of cooling water. Conventional cash flow analysis tends to favour fresh water due to the additional engineering costs associated with protecting equipment from the effects of salt water, a dilemma highlighted by Stegink *et al* (2003) when describing the range of projects undertaken by QAL during the drought conditions faced by the Gladstone region. However, when constructing a new alumina refinery in Gladstone during this time, Comalco elected to build in the flexibility of switching the cooling tower from fresh water to seawater more readily (Bechtel, 2006), although significant additional capital investment would still be required to operate in this manner. This is an example of one type of real options highlighted in the literature, and could be analysed using such a technique.
- Risk of discharge – Macintosh and Merritt (2003) described the application of a risk approach to quantification of the risk of accidental discharge of mine water, linking it to a decision point of when to proceed with a possible desalination strategy.

#### *Externalities*

Externalities and the distribution of costs and benefits from water use are an increasing focus for mining operations. However, there are fewer clear examples where valuation methodologies have been applied in this context.

- Choice modelling and option values – Rolfe and Windle (2005) describe the outcomes from a series of choice modelling exercises conducted in Central Queensland. Although not specifically focused on the coal industry, the study did seek to quantify community perceptions of the value of unallocated water resources for future use.
- Sustainability of freshwater sources – although difficult to attach value to, the impact of mineral operations’ withdrawals on existing water sources is very relevant to many sites. For example, the sustainability of the Great Artesian Basin is of importance to a number of companies operating across the eastern states. In a similar vein, a number of mining companies have adopted the global reporting initiative indicator of reporting freshwater consumption as a percentage of locally available resources (eg Argyle Diamonds, 2004).

#### *Integrating approaches*

Methods of integrating different types of value in the context of water and mining have tended to fall into the risk or MCDA categories.

- Qualitative risk and opportunity analysis – Evans and Roe (2003) described a project which sought to identify all the potential risks and opportunities associated with the supply of water from a river system in Central Queensland through a major pipeline to a particular mine site and associated community. This produced a profile of ranked issues covering economic, social and environmental areas, but did not go as far as attempting to produce a single index or summarising value.
- Multi-criteria methods – this approach tends to be favoured when comparing a discrete number of options. Within the context of the minerals industry, Giurco, Stewart and Petrie (2000) explore the application of MCDA in the evaluation of process options for copper production. Shaw *et al* (2001) describe a multi-stakeholder approach to the evaluation of options for treating the abandoned Zortman-Landusky mine site in the USA. In both these cases, specific water impacts are identified and attached a simple weight or value function.

## A case study

To illustrate a possible application of these concepts, consider the case of the management of saline water at coal mines in Queensland's Bowen Basin. This was the focus of recent analysis as part of a larger, ACARP-sponsored project 'Northern Bowen Basin water and salt management practices' (Moran, Côte and Macintosh, 2006). The larger project documented the multiple objectives that mines must meet in their management of water, developing a framework and simple system model to investigate the relationships between these often conflicting objectives. This project is described in more detail by Côte *et al* (2006). The following discussion will focus on one aspect of the work, and consider how various factors may be valued when managing the issue of salt.

## Background

The major coal mining regions of Australia exist in landscapes containing various types of salts in a range of stratigraphic positions and in a variety of geological and sedimentary settings. Salts present in overburden material, coal seams and groundwater systems mix and accumulate in processes and water storages on site. Most sites now recycle water from such facilities to some degree, but depend on supplies of fresh water to dilute salt loads and to make up for system losses. The implications of salt management in the coal industry have been the focus of research and study by individual companies and groups, including the feasibility of desalination technologies (Firth, 2005), the effect of saline water usage on maintenance costs (Bartosiewicz and Curcio, 2005) and the effect of saline water on coal flotation performance (Offori *et al*, 2005). However, as yet there are no examples of coal mines in the region adopting a formal salt management strategy, with the prevailing approach best described as passive acceptance of salt associated with reuse of water from mine storages.

The analysis set out to investigate the implications of moving from a position of passive acceptance of salt loads to managing according to specific objectives. The water objectives examined were:

- limit CPP clarifier salt concentration to 2500 ppm to eliminate product quality compromises, and
- limit CPP clarifier salinity concentration to 5000 ppm to obtain reagent savings benefit from salt water flotation.

Both objectives were examined using two strategies, desalination and dilution. This study was conducted using a simple system model of a generic coal mine site, which included the facility to blend fresh water with recycled water and water from a potential desalination plant.

## Internal financial analysis including hidden costs

Detailed data on water flows were obtained from seven mines (including both open cut and underground operations) in the Bowen Basin, and additional information on costs associated with the use of saline water and desalination adopted from the reports mentioned above. Analysis included the following direct and 'hidden' costs:

- An increase in maintenance costs associated with increasing CPP salt concentration, generated using a simple regression of data sourced from individual mines and the report by Bartosiewicz and Curcio.
- Annual per megalitre costs for water access and supply including allowance for pumping and maintenance.
- Desalination cost using electro dialysis based on amortised capital cost, operating cost and the additional expense of brine transport and sea disposal (Firth, 2005). Electro dialysis was selected from the options examined by Firth because it is the most well proven of the options.

Table 1 shows the cost estimates for the various scenarios in dollars per tonne of saleable product. There is considerable variation in the current cost efficiencies of the mines with the maximum (1.08) being 2.7 times greater than the lowest (0.40). When the scenarios are considered, in nine of 14 cases (indicated in bold) the modelling suggested equivalent or lower cost for the desalination approach. Clearly, small changes in the relative costs of purchasing and delivering water and desalination can tip the business case argument for one over the other. This underscores the potential importance of water price. Whilst it is true that the purchase price of water is not a large component of mine costs, things are more complicated when deciding whether or not to purchase more water to dilute or to take a technology path and install desalination. Equally important can be the influence of other related factors, such as increased maintenance costs due to high salt levels, and savings from reductions in reagent use. However, desalination uses less fresh pipeline water and therefore offers other potential additional benefits explored below.

**TABLE 1**  
*Differences in costs for water management*  
*(after Moran et al, 2006).*

	Cost \$/tonne product				
	Current	2500 ppm objective		5000 ppm objective	
		Dilution	Desalination	Dilution	Desalination
Mine 1	0.48	0.35	0.44	0.43	0.45
Mine 2	0.54	0.51	0.61	0.50	0.56
Mine 3	0.40	<b>0.41</b>	<b>0.40</b>	<b>0.38</b>	<b>0.38</b>
Mine 4	1.08	<b>1.23</b>	<b>1.23</b>	<b>0.92</b>	<b>0.92</b>
Mine 5	0.89	1.13	1.34	<b>0.76</b>	<b>0.76</b>
Mine 6	0.76	<b>0.80</b>	<b>0.79</b>	<b>0.75</b>	<b>0.75</b>
Mine 7	0.71	<b>0.75</b>	<b>0.72</b>	<b>0.72</b>	<b>0.71</b>
Mean	0.69	0.74	0.79	0.64	0.65
CV%	35	46	47	32	30

## Risk management

Somewhat paradoxically, in the current dry conditions experienced across the Bowen Basin there remain sites that retain sufficient water in worked water storages to run the risk of discharge under sudden wet conditions. Of the same seven sites used for the analysis, Moran, Côte and Macintosh (2006) identified three that modelling suggests spend over two-thirds of the time above 90 per cent full. The implementation of a desalination option would reduce the amount of new water being imported to site, and therefore result in a quantifiable reduction in this exposure, assuming similar on-site storage arrangements. It is acknowledged that there are other approaches of dealing with this issue, including the construction of larger on-site worked water storages, but these strategies are not without their own costs.

At the other end of the extreme, by reducing a 'dry' mine's dependence on large volumes of imported water, desalination also offers improvements in the risk profile for those times when supply is restricted due to drought conditions.

## Economic options

One obvious financial option is to sell the water freed by adopting a desalination path as a temporary trade. Recently-established water markets exist in this region to do this. Perhaps more financially significant is the value that the water can create by forming part of the supply needed for a new mine or a major expansion. If a new project is limited by partial unavailability of

water, the marginal cost of desalination on an existing site to make the water available for a new project is trivial compared to the value it will create. For example, if the desalination option to meet the 2500 ppm objective were implemented at the four sites where modelling suggested that the marginal cost was neutral or negative, when compared with the dilution option it would:

- free up 568 MLpa of fresh water, which would
- support additional production of 2.7 MT based on average usage rates from the same sites, and
- generate an additional \$324 M of revenue at current coking coal prices.

Additional analysis described by Moran, Côte and Macintosh (2006) shows that the potential 'opportunity profit' available is substantial, and also relatively insensitive to the cost of desalination.

### *Social and environmental values*

Other less direct benefits from additional water are also possible. For example, it may be of considerable benefit to a company to have the water available for town use. Community amenity (eg parks, gardens and sporting facilities) may have considerable value when there is strong competition to find and retain workers (and their families) during a skills shortage. Also valid, although somewhat less tangible, is the potential use of the water for provision of biodiversity values, for example, by providing on-site fresh water habitat and/or wetlands, and supplementing environmental needs. In an era when companies are attempting to meet goals such as realising net positive benefits in biodiversity (Rio Tinto, 2006), a little fresh water may go quite a long way. The importance of this has recently been underscored by the release on 23 June 2006 by the ICMM of the publication *Good Practice Guidance for Mining and Biodiversity*.

### *Summary*

The context of such a decision will obviously be critical to the outcome of a valuation process, and it is not suggested that desalination is a general solution to all water challenges in the Bowen Basin. The technology has its own 'hidden' costs and uncertainties, such as those associated with disposal of the brine. However, it is likely that a valuation process that takes into account factors such as reductions in contingency costs, potential unlocking of other opportunities or 'options', and the generation of value for other stakeholders and the environment could arrive at a different result than one that is focused purely on direct cash flow comparisons.

## CONCLUSIONS

The challenge of a fully integrated and multi-disciplinary valuation framework for water remains to be met. The difficulties of combining economic valuation with environmental and social dimensions have been explored by many authors, and as yet no consensus has emerged. However, consideration of the literature does highlight a series of focusing questions that are of relevance to any organisation operating in the minerals industry:

- How well do we understand the costs and benefits realised internally by our use of water? Specifically, can we account for the water we remove from local and regional sources, and do we quantify and allocate the costs of managing and disposing of that water appropriately?
- What risks, uncertainties and opportunities exist when considering both internal and external values associated with the management of water through our operations?
- What values are provided to other stakeholders in other locations along the hydrological cycle, and how does our use of water impact on and interact with such values?

There are an increasing number of methodologies available for answering these questions, which include but also go beyond conventional cash flow analysis. Further work to explore the topic is required, which focuses on ways of incorporating context into valuation processes, the use of different tools for different levels and types of decisions that relate to water, and methods of identifying and incorporating other stakeholder values into internal decision-making processes.

The application of more complex valuation processes will invariably demand additional resources, and any realistic framework must reflect the number and hierarchy of decisions which are faced on a routine basis by minerals operations. The most intensive processes are only likely to be applied for major project assessments. However, the principle of extending typical cost calculations to reflect not only risk and uncertainty, but also the concept of realising potential value for both internal and external stakeholders, is relevant at all levels and on every mine site.

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