Water management in mining – Measuring and demonstrating value-impact of management strategies

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Abstract Water quality in mining environments can be widely influenced by external factors and processes making difficult to measure the total impact of water management strategies. Stringent requirements demand best practices more than ever, and managing all aspects of water is critical as expectations of stakeholders and water users are diverse. Mine operators have to demonstrate that their strategies are designed to satisfy those expectations and are not only for compliance. This paper addresses these imperatives in a framework responding to those identified drivers. A case study shows the evolution of water quality in response to driven efforts in managing water quality.

Key words water, quality, mine, management, environment

Introduction

Water quality in mining environments is influenced by activities associated with mineral extraction or mineral processing. Water is the main transport mechanism carrying out pollution within and outside the mine site. Natural and industrial processes distribute widely water constituents into the environment and sometimes in concentrations exceeding regulatory standards. Stringent requirements from the public and regulatory agencies demand best management practices more than ever. Business and organizations formulate their management strategies based on these requirements. For instance, mining companies formulate their environmental management strategies based on the environmental commitments established in their EIA, EIS and Closure plans. Managing all aspects of water is critical and difficult as expectations of a variety of stakeholders and water users can be diverse. Hence, water management strategies should respond to these expectations and align with the regulatory requirements and guidelines for water quality protection.

Methodology

Measuring environmental performance is challenging when the monitoring criteria focus on compliance of inputs and outputs alone. As a result, more than often the functional activity of monitoring becomes a status quo that can prolong the need for the primary design.

Figure 1 Integrated water management framework proposes a framework standing on knowledge management support throughout the life of mine. A review and assurance of the water management strategy and all associated elements are paramount for a successful implementation.

The most practical approach for a mining company to measure water quality variability is to conduct monitoring but demonstrating sustainable performance could become difficult

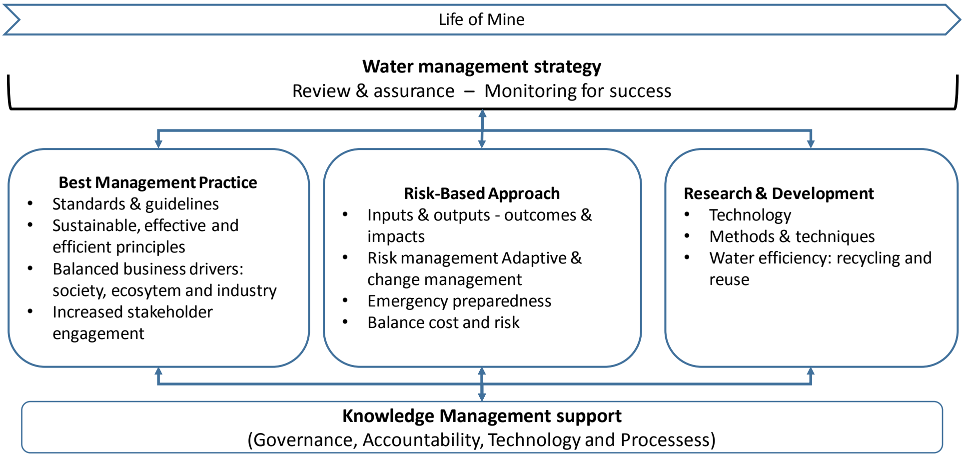

Figure 1 *Integrated water management framework*

when the monitoring criteria lack clarity. Companies require a better and a quantitative understanding of the performance of their management strategies.

The total impact of management strategies is a function of the combined environmental, social and economic impacts. In this approach, monitoring for success extends beyond tracking changes in the water quality of the effluent downstream and includes tracking changes in the catchment system in response to management strategies over time. Hence, monitoring not only targets defined and agreed water quality parameters, but also seeks to confirm the outcomes and impacts anticipated in management strategies. In this context, the paper presents a monitoring context shifting from inputs and outputs, towards outcomes and impacts (Figure 2 Effectiveness of water quality measurement criteria adopted in monitoring programs).

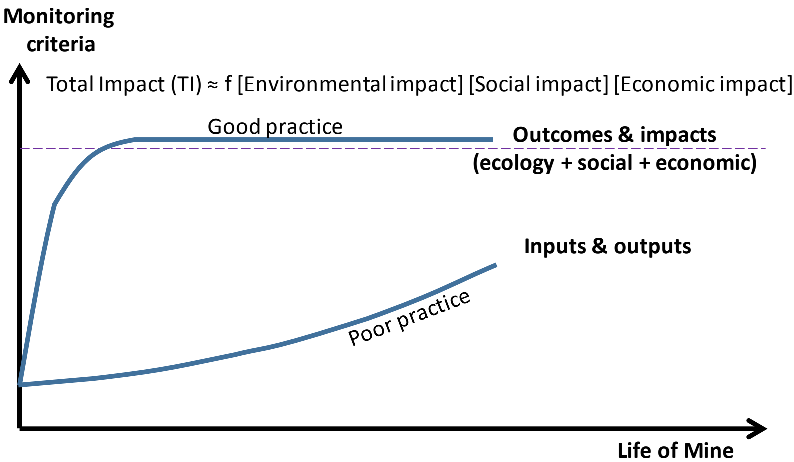

Figure 2 *Effectiveness of water quality measurement criteria adopted in monitoring programs*

By measuring these outcomes and impacts, businesses and organizations can calibrate their strategies and understand whether these are working or not.

Case study

The former Brukunga mine site is located 50 km east of Adelaide in the Adelaide Hills eastern of the Mount Lofty Ranges (Figure 3 Former Brukunga mine site is located 45 km to the east of the city of Adelaide in South Australia (Source: Geoscience Australia 2017)). The mine operated from the 1950s through to 1970s extracting and processing iron sulphide to source sulphur for the production of sulphuric acid and fertilizer. The site occupies approximately 165 hectares comprising open pits, 8 Million tonnes waste rock and 3.5 million tonnes of tailings. Environmental issues arising from the former operation included low-grade sulfidic ore in waste rock dumps adjacent to the local Dawesley Creek, exposed fresh sulphide mineralization on the quarry floor, tailings storage facility, acid water seepage and pollution of natural drainage. The mine site rapidly became a source of acid drainage with the generation of potential contaminants (Taylor and Cox 2003).

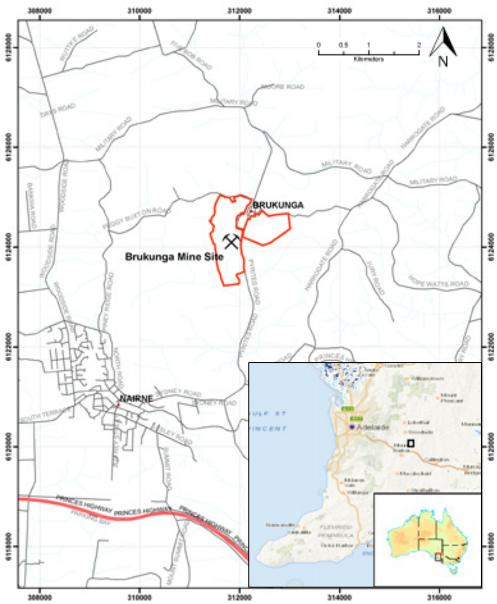

Figure 3 *Former Brukunga mine site is located 45 km to the east of the city of Adelaide in South Australia (Source: Geoscience Australia 2017)*

Following the cease of operations at the former Brukunga mine site, the water quality was impacted in local the creek along the way for nearly 70 km of flow stream representing almost 43 km in a straight line and affecting farmland, agriculture and ecosystems.

The Brukunga mine affected the socio-ecological system of the local Dawesley Creek including associated terrestrial ecosystems, local families and businesses using these ecosystems. As a result, properties downstream of the mine were advised not to use water from the creek and were compensated with subsidized water supply. The former mine became a financial and environmental liability to Government (Armstrong and Cox 1977).

In 2001, the Government committed funding to conduct remediation works and to improve water quality in Dawesley Creek. Under the guidance of a team of experts, the site has been subject of extensive research to identify a suitable whole-of-site strategy to remediate the site. The mine site is currently undergoing rehabilitation but water management at the site continues. A water management infrastructure continues to collect, intercept and treat acid and metalliferous drainage (AMD) generated at the site in order to manage water quality in the local creek.

Management strategy and water quality criteria

A whole-of-site remediation strategy outlines the strategic objectives below:

- Improve water quality in Dawesley Creek to a standard as good as possible.
- Substantially limit or avoid the need to intercept and treat acid waters indefinitely.
- Return all or part of the site back to productive uses or for environmental/ ecosystem values.
- Apply leading practice to site management and mine completion.

The strategy establishes the objective for water to meet quality standards in the local creek in agreement with the demand of downstream water users; i.e. irrigation and livestock. A water quality criteria to meet environmental and ecosystem values is monitored following the jurisdiction policy and guidelines for water quality (Table 1) (Stevens and Fullston 2015).

Parameter	EPP 2003 [(1)]			ANZECC 2000 [(2)]		
	Aquatic ecosystem(a)	Agriculture (b)	Livestock (c)	Freshwater (d)	Irrigation (e)	Livestock (f)
pH	6.5-9	4.5-9		6.5-9	6-9	id
EC (µS/cm)				100-5000	7000-7500	4000-5970
Sulphate (mg/L)			~1000			~1000
Aluminum (mg/L)	0.01	1	5	0.08	5-20	5
Cadmium (mg/L)	0.002	0.01	0.01	0.0004	0.01-0.05	0.01
Copper (mg/L)	0.01	0.2	0.5	0.0018	0.2-5	0.4-1
Iron (mg/L)	1	1	id	id	0.2-10	
Manganese (mg/L)		2		2.5	0.2-10	
Zinc (mg/L)	0.05	2	20	0.015	2-5	20

***Table 1** Water quality standards as requirement for the water quality monitoring criteria*

(1) South Australia Environment Protection Authority – Environment Protection (Water Quality) Policy 2003 (SA EPA 2003)
(2) The Australian and New Zealand Environment Conservation Council – Australian and New Zeland Guidelines for Fresh and Marine Water Quality (ANZECC 2000)
id insufficient data

Water quality program

- Pre-diversion (1998-2003). Partial relocation of waste rock dumps, tailings covered with bio-solids, vegetation to reduce infiltration and promote evapotranspiration.
- Post-diversion (2004-2014). A major diversion of clean waters to bypass the mine site and upgrade of the treatment plant.
- Post-diversion extended (2014-2015). Improvements in the diversion system. Increased interception and treatment prior to discharge.

Monitoring of water flows, water quality and riparian ecosystem to measure the effectiveness of the strategies in accordance with the standards of the jurisdiction in Table 1. From 2016 water quality is monitored against ANZECC 2000 guidelines only.

Results

The primary focus of intervention has been to address the water quality in the local creek and the main indicators of water quality are the standards presented in Table 1 and in accordance with the South Australian Environment Protection Authority (SA EPA) and the Australian and New Zealand Environment Conservation Council (ANZECC).

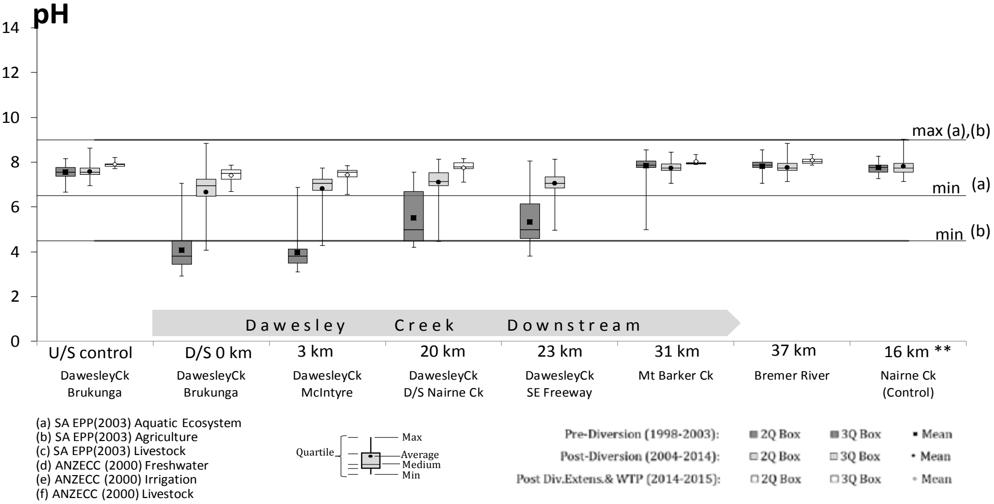

Figure 4 *Progressive improvements on pH values as one of the main indicators of water quality (** tributary control 16km downstream, data source: Brukunga water monitoring reports)*

The water quality in Dawesley Creek improved progressively after numerous works at different times. Figure 4 Progressive improvements on pH values as one of the main indicators of water quality (** tributary control 16km downstream, data source: Brukunga water monitoring reports) shows the changes in pH readings at different points in Dawesley Creek. The dark grey indicators show the pH levels pre-diversion of Dawesley Creek (1998-2003), the light grey indicators show the average readings post-diversion (2004-2014), and the white indicators represent the current levels since the extension of the Dawesley Creek diversion and improvements in the treatment plant (June 2014-2015). Other parameters have also shown trending improvements in water quality with moderate volatility (Figure 5).

The information derived from the monitoring program shows pH levels are within the range for both agriculture and aquatic ecosystem. Salinity meets the standards for the aquatic ecosystem, agriculture and livestock. Sulphate in relation to water for livestock remains volatile and outside threshold immediate to the mine site but it recovers at 3km downstream. Aluminium in water has improved and is within the threshold for livestock but outside the threshold for agriculture to 20km. Aluminium is a naturally occurring element in Dawesley Creek and does not meet criteria for the aquatic ecosystem to the full length of the creek. Cadmium in water is within the threshold for agriculture and livestock, but above the threshold for the aquatic ecosystem to 20km. Copper is within the threshold for agriculture, livestock and the aquatic ecosystem. Iron is a naturally occurring element in Dawesley Creek and it was always outside threshold for both agriculture and the aquatic ecosystem. It is improving but the condition remains down to 20km. Manganese control has improved and is within the threshold for ag-

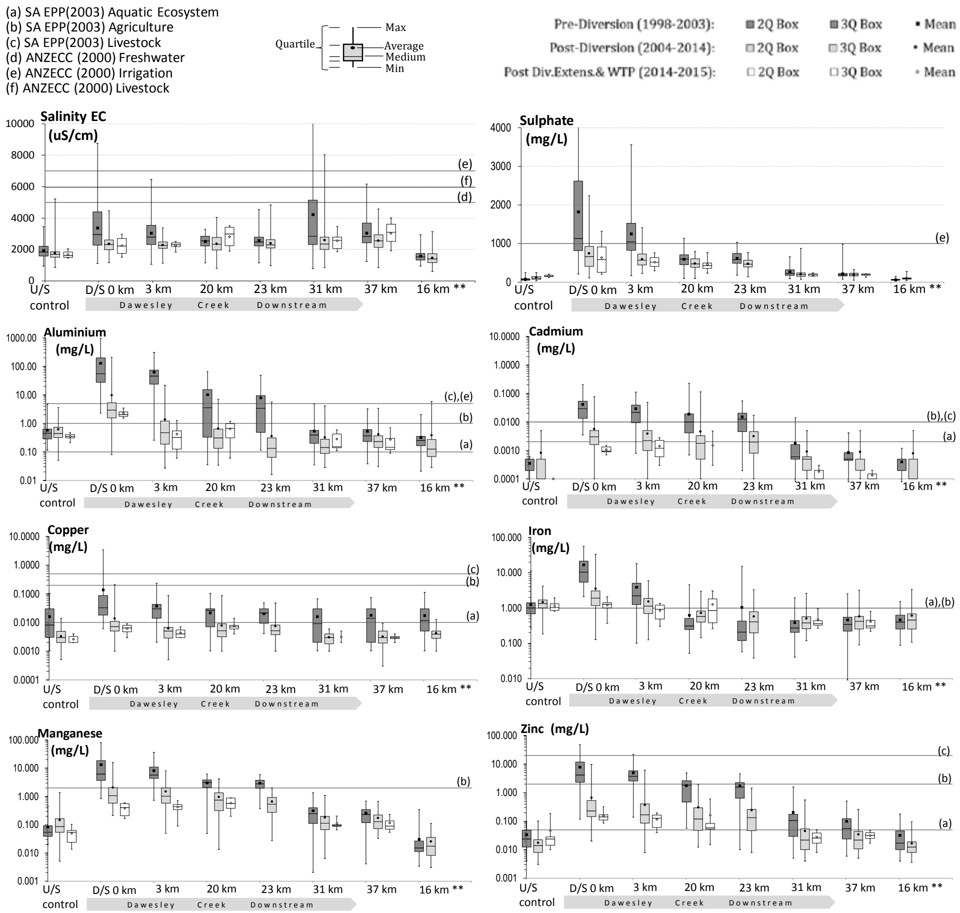

Figure 5 *Temporal and spatial variability of water quality in Dawesley creek in response to management strategies (Data source: Brukunga water monitoring reports).*

riculture water. There is no threshold for livestock. Zinc is within the threshold for livestock and agriculture but outside the threshold for the aquatic ecosystem to 20km but improving.

Conclusions

A comprehensive water quality program incorporates the needs of other water users.

Monitoring temporal and spatial variations of water quality can allow constructing a representation of the trends and the effectiveness of the management strategies. The complexity in identifying the future conditions of the catchment system arises when the variability in water quality is due to non-point sources and where the strategy has limited control.

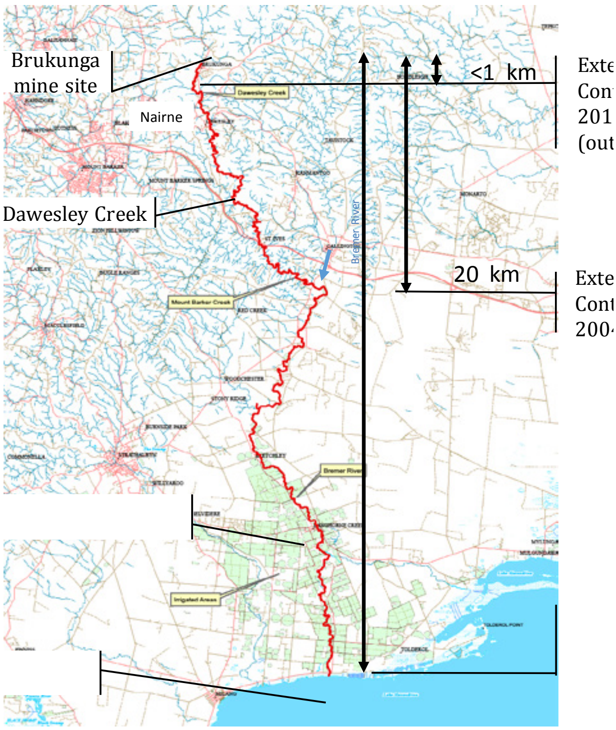

***Figure 6** Water quality improvements with reference to agriculture irrigation & livestock quality standards (Mollehuara 2016)*

A monitoring program that aims agreed criteria for water quality could demonstrate the improvements as a result of the works conducted in the water quality program (Figure 6 Water quality improvements with reference to agriculture irrigation & livestock quality standards (Mollehuara 2016)).

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