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Systems modelling for effective mine water management

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ABSTRACT

Concerns about the difficulties in securing water have led the Australian coal mining industry to seek innovative ways to improve its water management and to adopt novel strategies that will lead to less water being used and more water being reused. Simulation tools are essential to assess current water management performance and to predict the efficiency of potential strategies. As water systems on coal mines are complex and consist of various inter-connected elements, a systems approach was selected, which views mine site water management as a system that obtains water from various sources (surface, groundwater), provides sufficient water of suitable quality to the mining tasks (coal beneficiation, dust suppression, underground operations) and maintains environmental performance. In this paper, the model is described and its calibration is illustrated. The results of applying the model for the comparison of the water balances of 7 coal mines in the northern Bowen Basin (Queensland, Australia) are presented. The model is used to assess the impact of applying specific water management strategies. Results show that a simple systems model is an appropriate tool for assessing site performance, for providing guidance to improve performance through strategic planning, and for guiding adoption of site objectives.

1. Introduction

The mining industry is a significant contributor to the Australian economy, representing almost 10% of the country's economic activity and around a third of all export income (Hooke, 2007). Water is integral to virtually all mining activities and access to secure water supplies is crucial to mining production. The Bowen Basin (Queensland, Australia), one of the world's important coking coal mining regions, recently experienced a prolonged regional drought that coincided with a significant rate of growth in production. It was facing difficulties in securing water supplies that could not be entirely solved through the traditional approach of developing regional water infrastructure. The drought also led the Australian coal mining industry to recognise that there was scope for improving water management.

A coal mine can consist of open-cut operations (where the coal seam is located relatively near the surface and coal can be extracted following removal of the overlying rock), underground operations (where the overlying rock is left in place and the coal removed through shafts or tunnels) or both types of operations on the same site. Many coal mines have a coal handling and preparation plant (CHPP) on site. Water is used in the CHPP (if present), for dust suppression, vehicle wash down and potable uses. Dust suppression is needed in pits, on roads and in industrial areas.

With severe droughts imposing on the mines to reduce their consumption of fresh water, alternative water sources have been sought, such as worked water, which in this paper is defined as water that has been involved in a task or has passed over (or through) an area disturbed by the mining processes. It includes runoff intercepted by mining pits, groundwater inflows, wash down residuals, and output from the various tasks, such as the water that has been used in the coal preparation plant. Some of the issues that arise from the increase in worked water use are related to water quality management, and more particularly increases in salt concentration. Worked water can potentially be used for all tasks on open-cut mines, but in practice there is a great deal of variation in the tasks to which worked water is applied. A barrier to increasing worked water use is a lack of information on its impacts. There is a requirement to balance the corrosion costs associated with using worked water with the costs of water treatment (essentially desalination) and/or importing more fresh water. For underground mining, only fresh water is used to protect the health and safety of miners and to minimise corrosion of underground equipment (Cote et al., 2007).

Sufficient water supply must be available, as production cannot proceed if there is no water available for dust suppression, the CHPP and underground operations. In addition, any water that has been contaminated through contact with disturbed areas must be stored appropriately and can only be discharged to the surrounding

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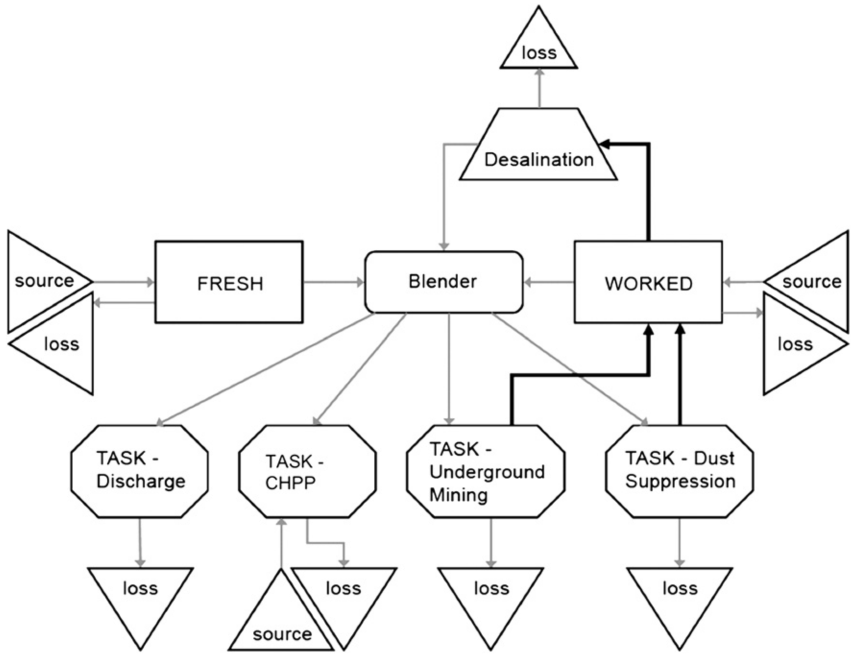

Fig. 1. System diagram of a simplified coupled salt and water balance model for a coal mine (Cote et al., 2007).

environment if it meets specific criteria, usually expressed in the form of a discharge license (Barger, 2006).

The engineered water circuit comprises collection, storage, distribution, losses and release. Water is collected from a range of sources, which often includes an allocation of fresh water, delivered via specific infrastructure such as a dedicated pipeline. Additional sources of water may be on-site runoff capture and aquifer inflows. Water is stored on-site in purpose-built dams and in the pits from where mining has ceased. Large coal mines can have a complex network of water stores. For instance, one of the mines that participated in this study had 8 storage dams and 10 old mining pits that were used for water storage, and a complex infrastructure network to transfer water among all these elements. Water quality in these storages can vary widely depending on the type of water that is collected (e.g. fresh water, runoff capture, worked water) and the condition of the medium through which it is collected.

We define an effective coal mine water management system as one that: (1) meets operational constraints, such as avoiding production losses due to water shortages and abiding by discharge license requirements, (2) maintains worked water at appropriate salt concentrations and (3) adopts novel strategies that will lead to less water being used and more water being recycled. These three elements constitute what Checkland (1981) terms the root definition of a system and this term is adopted here when referring to these elements.

As water circuits on coal mines can be complex, simulation tools are essential to assess how well a coal mine water system performs with respect to the root definition and to predict the efficiency of various management strategies. Currently, the modelling techniques that prevail in the field of mine water analysis are anchored in process-based approaches (Jakeman et al., 2006). They aim at studying in detail one isolated aspect of mining and water interactions: the impact of mining on groundwater (Younger et al., 2002) and on acid mine drainage (Banks et al., 1997; Liang and Thomson, 2009; Mayer et al., 2003; Younger, 2000); water balance modelling (Bru et al., 2008) or hydrochemical modelling (Schwartz et al., 2006) of tailings dams, where fine waste is stored; or the design of mine water dams using industry-accepted hydrological softwares (Laurenson and Mein, 1990; WP Software, 1994). None of these detailed approaches can be used to assess the performance of a mine water system and increasingly, mining companies rely on consulting engineers to develop operational models. There are as many types of these engineering models as there are consulting companies, but they are similar in structure. They represent all catchments, storages, reticulation and pumps, along with the operational rules that dictate transport rates in the distribution system. An example of such model is described in McIntosh and Merritt (2003) with runoff calculated with the Australian water balance model (Boughton, 2004).

This type of model is essential for day-to-day operations as it can provide mine management with risk-based guidelines for both securing and containing mine water inventories (McIntosh and Merritt, 2003). It can also be used for detailed planning of major changes to the site and feasibility analysis for new projects (McIntosh and Merritt, 2006). However, their structure is not well adapted to assess the performance of the water management system as it includes elements that are not meaningful at this strategic level of interest whilst it excludes elements that form part of the root definition. For instance, the maximum pumping capacity that is available to move water from one storage to another does not impact on the overall status of water stocks and thus is not meaningful to assess whether sufficient supply will be available for the life of the operation. Conversely, the salt concentration of water stored in one pit may not impact on daily water movement, but can

Table 1
Rainfall to runoff coefficients.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall/runoff coefficient	0.195	0.245	0.136	0.044	0.03	0.023	0.020	0.006	0.012	0.057	0.100	0.132