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Water management systems in Australian mines

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ABSTRACT

Replies to a comprehensive questionnaire on mine water resource management systems (WRMS), which were distributed to a selection of Australian mining operations in 1991, are analysed. Although the replies cannot be considered fully representative of the industry, they do provide a good qualitative indication of water resource management in the industry at that time.

Within Australia's largely arid land mass, a majority of mines normally need to conserve water, a few need to dispose of water and a number face a seasonally varying position. An assessment of the importance of WRMS compared with management of ore extraction and processing is given. A risk assessment of failure is given; there is more acceptance of WRMS failure in the mine compared with the mill. An assessment is made of considerations in WRMS design. Managements are generally pro-active in the design of WRMS and in the setting of performance standards. The operational characteristics of mine systems are examined in detail.

Companies generally do not appear to allocate sufficient resources for the collection of basic WRMS monitoring data and knowledge of the water budget to efficiently manage the system. This indicates scope for considerable cost savings in most mines.

INTRODUCTION

There is limited information on mine water resources management systems (WRMS) within the published literature. In order to gather current Australian information on mine WRMS for a PhD research program a questionnaire was prepared and distributed to mining companies. This was structured to obtain information within three main areas:

1. the importance of the mine WRMS as compared to management of production and if any risk of production shut down is acceptable due to failure in the WRMS;

2. the techniques used in the design and development of mine WRMS; and

3. on-going monitoring and performance assessment of the WRMS.

General information about the questionnaire is briefly summarised. The analysis of the replies is organised into three sections: the importance, the design, and the operation of mine WRMS. Conclusions complete this paper.

The term 'company' is used to refer to an individual mining operation. The terms 'mine' and 'mill' refer to the ore extraction and processing sections of the mining operation respectively, except for 'mine WRMS' which refers to the entire operation.

GENERAL INFORMATION

The prepared questionnaire was distributed to 144 mining companies. The companies were selected from the *Register of Australian Mining*, 1988/89 edition (Louthean, 1989). The selection process was based upon perceived size, location and mineral extracted, and attempted to provide a representative cross-section of mining within Australia.

Completed questionnaires were returned by 30 companies with four others declining to complete the questionnaire. In terms of mining method, one operation was underground with five companies operating both underground and open cut systems. Mine operational size in terms of ore extracted varied from 120 000 to 8 000 000 tonnes per year (Table 1).

TABLE 1

Tonnes of ore mined.

Type of mineral extracted	Number of mines surveyed	Tonnes of ore mined (range, '000 tonnes/year)
Gold	17	120 - 1500
Coal	6	1400 - 8000
Bauxite	2	6000 and 5500
Copper	1	460
Lead/zinc	1	1100
Magnetite	1	6000
Manganese	1	4000
Uranium	1	5000

Operation life expectancy of companies varied from ten months to greater than 20 years (with two non-replies) life expectancy distribution is summarised in Table 2. Six companies had been closed at some time during their history pointing to the small profit margins of some operations.

TABLE 2

Expected operational life (years).

Life < 5	5 ≤ Life <10	10 ≤ Life < 20	20 < Life
10	4	3	11

The need to conserve or waste water is most often related to the annual rainfall and its distribution over the year. The majority of the companies surveyed (23) were located within climatic regions receiving less than 1000 mm average annual rainfall. The WRMS aim to only conserve water was reported by 18 companies. The main management technique used to minimise new water input to the process water system is water recycle from the tailings dam. However, where water conservation requirements were indicated there was no evidence that minimisation of evaporation was attempted or designed into the WRMS. The WRMS aim to only waste water was a requirement of five companies. The remaining seven companies were faced with having to waste and conserve water depending upon the time of the year, the source and quality of the water and its location within the mine WRMS.

All operations used considerable quantities of water within both the mine and mill. Typically the quantity of water transferred in association with ore beneficiation comprised over 90 per cent of the total water transferred within the WRMS.

IMPORTANCE OF THE MINE WRMS

While the WRMS is an essential non-core component of production, it is of interest to establish both the importance and the cost of the system.

Companies were asked to rate the importance of the WRMS relative to management of ore extraction and processing. Results are summarised in Table 3. Within the 'more important' category, two companies conserved water and the third was heavily regulated and relied on tight control of its water to remain within Government operating guidelines. For the majority of companies, there was no obvious association between the reported importance of the mine WRMS and the normal parameters which affect mine WRMS, such as annual rainfall, initial capital cost, operating cost and system failure.

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TABLE 3

Importance of the mine WRMS as compared to ore extraction and processing.

Less important	As important	More important
50%	40%	10%

As an engineering concept, it is theoretically not possible to build and maintain a WRMS that has zero risk of failure. Each company was asked to quantify their level of acceptable risk of shut down in the mine and mill resulting from a failure in the mine WRMS (Figure 1). The probability of failure terminology 1/1000 represents one day lost in 1000 days of operation.

It can be seen that there is more acceptance of failure in the mine compared with the mill which is explained by the ability of the mine to stockpile sufficient ore for continued milling in the advent of a mine shut down. The stockpiling of ore for at least one week of processing was a typical practice of the companies answering the questionnaire. Interestingly, failure in the WRMS resulting in a mill shutdown had occurred in about half the companies that had indicated an accepted failure rate less than one in 10 000. The actual failure rate has been higher than the desired rate and resulted primarily from pump breakdown rather than a water shortage. Fifty per cent of all companies had experienced a mine shut down, the majority being caused by flooding. Most companies increased their pumping capacity after a flood event. Several companies have been prepared to give operational acceptance to shutdown periods due to flooding and allow for these periods in their annual production plans.

It would be expected that a company with a long operating life would be more likely to invest capital to improve the WRMS response to variations in climate. The survey did not indicate this, with no correlation between risk of mill failure and an initial high construction cost (greater than $50 million) or with an expected long operation life (greater than 20 years).

The construction and operating costs of mine WRMS may increase in the future due to tighter Government guidelines on the management of water disposal from mines. The Queensland Government (1990), through the Department of Environment and Heritage, has prepared environmental guidelines for mines using cyanide and has developed environmental guidelines for all mines with an emphasis on water management and rehabilitation (Queensland Government, 1991). Similar actions have occured or are occurring in all other States and Territories

For 18 companies, the day-to-day responsibility for the operation of the WRMS lay directly with the mine or mill departments. For the remaining 12 companies, their support departments, such as technical services, operated the system. Advice on the development of the system is provided by either internal specialist groups, outside consultants or a combination of both.

DESIGN OF THE MINE WRMS

At the design stage all the major water supply systems are planned. If the design is in serious error it may be difficult to later modify the system to store or provide more water. Due to changing Government requirements for the control of rainfall run-off water, one company indicated that it had to store a one-year supply of water (800 000 m^3) in one side of a split pit system while a water storage pond was deepened.

The estimation of the water resource volume and availability over the year is the core step in designing a WRMS. The annual water consumption is typically comprised of a constant component such as process requirements and a seasonal component such as dust suppression water.

The two sources of new water input to a WRMS are rainfall run-off and imported water (groundwater, creeks, reservoirs). The water may be sourced locally or by necessity piped from a source. Annual rainfall is random and patterns can be described statistically. Estimation of rainfall run-off means consideration of both the rainfall pattern and the characteristics of the catchments. The calculation of water yield requires considerable estimation of

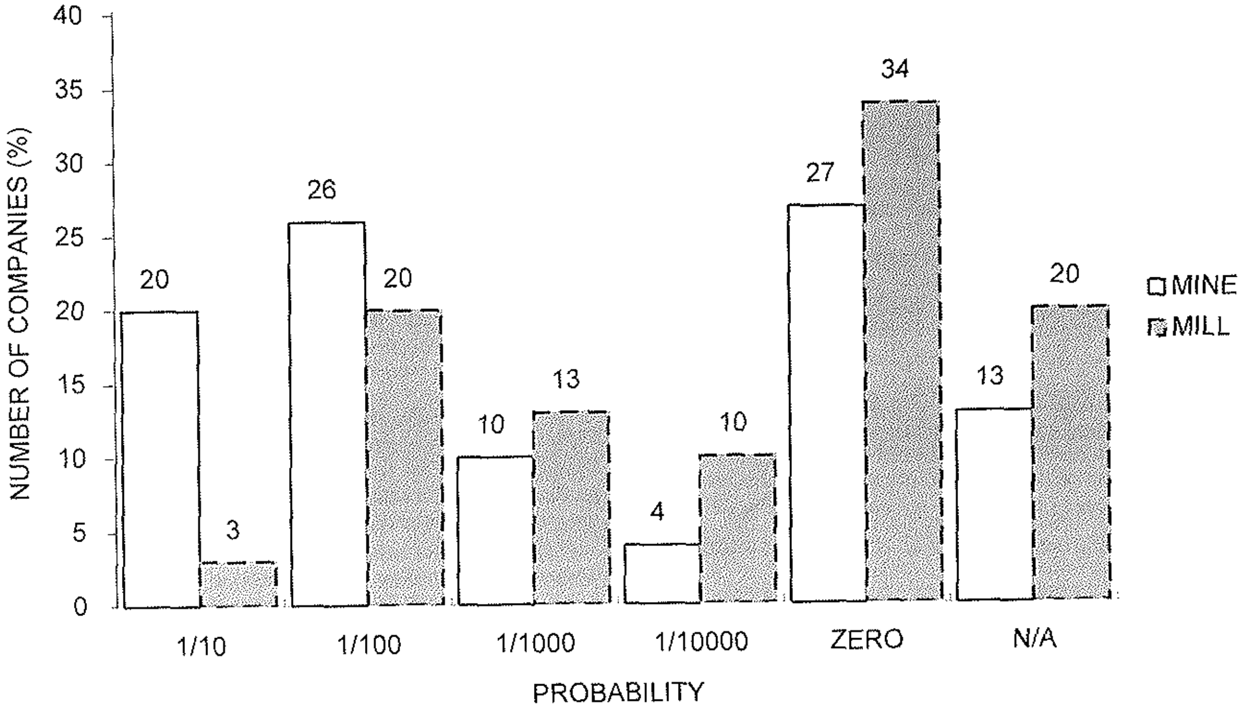

FIG 1 - Acceptance of failure of WRMS in the mine and mill.

input parameters. Groundwater sources are less variable and estimated from pump tests. The aquifer water level draw down data for an operational bore field is often periodically re-evaluated using data collected during operation.

Generally, mine water supply systems comprise both surface water and groundwater components as indicated in Table 4. Groundwater is often unsuitable for direct use as potable water and may require desalinisation. This is a particular problem in parts of Western Australia, where groundwater is more saline than sea water.

TABLE 4

Water supply sources.

Groundwater only	Surface water only	Both sources
5	0	25

In order to estimate net surface water yield, four essential parameters are required, namely

1. fainfall,
2. lake evaporation,
3. catchment size, and
4. catchment run-off characteristics.

Many other parameters may be incorporated into the design process to meet operational or Government criteria. The major parameters that may be incorporated in the design of a mine WRMS are listed in Table 5, together with the number of companies that actually used the parameter in their design process.

TABLE 5

Parameters used in the mine WRMS design.

Parameter	Used	Not used	N/A	Did not know
Annual rainfall quantity	26	3		1
Rainfall distribution	19	10		1
Lake evaporation	17	12		1
Operation catchment areas	20	8		2
Mine water requirements	22	6	1	1
Process water requirements	25		5	
Water supply options	25	5		
Water quality	25		5	
Water disposal options	18	12		
Mine dewatering	30			
Projected operation life	17	11		2
Company management requirements	22	8		
Stage development	15	15		
Government environmental requirements	28	1		1
Public or land owner requirements	15	9		6
Mine rehabilitation	14	15		1

All companies use or need to manage surface water to some extent in their operation. Annual rainfall was not stated as being used in four cases of mine WRMS design, however, it should be noted that companies in this category relied on groundwater only to meet their water needs. The distribution of rainfall throughout the year is important where there are distinct wet and dry periods. A mine may need to store sufficient water for up to eight months of the year and then cope with the potential of too much water. Combinations of water shortages followed by floods are uncommon, however, they occurred in northern Queensland in 1990/91.

Evaporation is a water loss from the system and is therefore an extremely important component in the design of the mine WRMS. In designing the WRMS a knowledge of the evaporation rate mean and variance can be used to minimise or maximise the loss of water from the system to the benefit of the operation. This parameter can not be directly measured in practice and so is estimated indirectly. The most common method currently used to estimate evaporation uses water loss measurement from an Australian evaporation pan with bird guard (Gan and McMahon, 1986). The pan data are converted to lake evaporation by the application of an appropriate conversion factor.

Sixty-seven per cent of mining companies included catchment size and run-off characteristics in their design procedure. Based on the information provided by the companies, 17 mining companies incorporated the minimum four parameters for surface water resource assessment. Apart from those companies using groundwater, it is not clear how the remaining eight companies determined the surface water resources, unless surface water supplies form only a small portion of the requirements and are used only when available and treated as a bonus.

All companies which beneficiate ore considered process water requirements and the various options for water supply. Water quality for processing was considered by most companies, those of exception used little recycle. Recycling of tailings dam water may be employed as a means of reusing process reagents. Alternatively, recycle water can contain dissolved solids at concentrations which may precipitate within the pipe supply system or decrease extraction efficiency. Evaporation is a very effective way to concentrate the dissolved solids within dam water.

Disposal options for water were considered in 18 cases. Surprisingly, three mines which had to waste water did not consider disposal options. In these cases it was surmised that the water was of high quality and disposal had met with Government disposal controls as all but one company had considered Government environmental requirements in the design.

Pit dewatering was considered at the development stage of the mining operation by all 30 companies surveyed. The need to consider dewatering for pit design is usually alluded to during the exploration and delineation of the orebody. The use of this water within the WRMS is usually only of secondary importance, but can be an efficient way of meeting the two independent objectives of pit dewatering and water supply in a cost-effective manner.

The anticipated operational life was considered by 17 companies. Companies having a life expectancy less than 20 years tended to require a lower risk of failure within the mill due to the WRMS. This is contrary to the expectation of short-term operation/higher risk. Staged operational development of the WRMS to coincide with the expansion of production was considered in 15 cases. The life expectancy of the mine (and possible expansion) is an important consideration where the company is using a groundwater reserve of limited extent or in the decision of capital investment verses operational expense for the WRMS. The compromise between capital investment and operational expense is associated with risk of system failure. Occasionally markets for commodities can change rapidly, requiring a fast response to maintain viability or maximise returns. The carting of water by tanker has been used as an interim measure to meet increased production and the associated water consumption while the WRMS was modified to meet the increased product output.

Considerations of land ownership has always been necessary in mining. Aboriginal groups across Australia are having an increasingly important input into mining operations. This input includes consent to develop or not to develop, as in the cases of the Coronation Hill Joint Venture project in Northern Territory and Yakabindie in Western Australia. Where mining is approved, Aboriginal groups usually have significant input into guidelines for the operation of the mine. For example, there have been requirements for a no-release WRMS, certain operational environmental standards and certain standards for rehabilitation. Landowner requirements were considered by 15 companies.

The majority of companies (16) used both consultants and in-house expertise to design the mine WRMS. Nine used only consultants with five using only in-house expertise.

The techniques used in the design of the company WRMS are summarised in Table 6. The most common approach used in designing mine WRMS is based on estimated or assumed rainfall run-off relationships with some form of parameter sensitivity analysis.

TABLE 6

Design techniques.

Technique/Reply	Yes	No	Don't know
Broad engineering skills	28	0	2
Regional experience	18	6	6
Computer modelling	12	14	4
- *deterministic*	2		8
- stochastic		2	8

The design review is an important step in selecting the most appropriate WRMS design. Only two companies did not review the mine WRMS design internally, relying on the expertise of their consultants. These two companies were relatively small with no internal expertise in WRMS. The appropriate State Government Department reviewed the design of the WRMS in 20 cases (one 'don't know'). Eleven of the companies completed an environmental impact statement and review process (one 'don't know'). As a result of the review process, 14 companies modified the proposed design (three 'don't knows'). The representative Government Department required changes in six designs resulting in increased costs to the companies.

OPERATION OF THE MINE WRMS

Informed decision-making on water management strategies requires some form of performance monitoring through collection and analysis of data. These data can encompass the minimum four parameters for an analysis of the surface water resource and include pond volumes and transfers of water to key areas. Major modification or development of the system can be designed with greater certainty if site operational data are collected. However, data are expensive to collect and are often not used for many years, if at all.

A series of questions was structured to provide information on data collection and to permit basic water balances to be calculated. Catchment area of the mine pits, rock dumps, water holding ponds and tailings ponds were periodically recorded by six, three, eight and nine companies respectively. Only three companies recorded the areas of all four catchment types.

The need to transfer water about the operation is common. Collection of data is time consuming and often the operational accuracy of water meters is poor. Water transfers were recorded to the mill and from the mine in 18 and 14 cases respectively and transfers from the rock dump catchments were recorded in only four cases.

Six companies did not know how much water (on average) originated from run-off or creek flow. The majority of companies collected data on the amounts of water sourced from ground water, recycle or municipal services. All companies were able to provide water quantities used by the mine, mill, personnel and that supplied to support towns.

The results of the basic water balance calculations using data supplied showed that six companies had supplies equivalent to only 40 to 60 per cent of water required for operation, with one company not knowing how much water was derived from the various sources. Two companies appeared to be pumping more groundwater than needed for the operation (this did not include those companies dewatering workings). Sixteen of the 19 companies recycled approximately 45 per cent of mill requirements with a further three companies stating greater than 100 per cent recycle of mill requirements (implying an error).

Ten companies had to handle at least 20 per cent more water than they required for the operation. The disposal methods for excess water are summarised in Table 7. The most popular method is maximising evaporation, usually by preferential transfer of water to the largest water surface pond.

TABLE 7

Water disposal methods.

Method	Companies
Maximise evaporation	30
Passive discharge (eg spillway overflow)	7
Active discharge (eg pumping)	2
Irrigation	3
Water treatment and release	2
Three or more methods	3

Twenty companies had the mine WRMS performance reviewed as part of on-going operational refinement. Of these, 13 stated that their design was appropriate, four indicated under-design and five over-design. It is not clear what data was used in the reassessment of the mine WRMS, as few mines collected what could be considered the minimum data necessary for a basic water balance.

SUMMARY AND CONCLUSIONS

Thirty questionnaires were returned completed, which constitutes a small sub-set of the industry. Therefore, it is not possible to say that the replies provide a fully representative cross-section of the mining industry as the replies may have originated from one sector, such as large sized mines, more than others. The information in this paper should be viewed as a qualitative indication of water resource management in the industry.

Generally, mine WRMS are considered less important than ore extraction or processing and comprise a minor percentage of the capital and operation costs. Accepted risk of WRMS failure in the mine or mill was low with approximately 30 per cent of companies requiring zero risk.

The companies generally had a good understanding of the day-to-day water requirements of their operation but were less knowledgeable about the design of the system. This is consistent with the need to know how production is performing to maintain profitability. There is less need to know the history of the design or the operational range of the WRMS if the system is performing acceptably.

If there is a planned expansion or a need to modify the WRMS, it becomes more important to record system performance information. Data collection for good design was generally not evident from the replies.

Governmental controls placed on the companies were not perceived to limit the operation of the mine WRMS or add considerably to the cost or management of the system, with one exception. This is likely to change in most Australian States as Governments tighten environmental controls on the management of water associated with mining operations. While these changes may be generally considered an unnecessary nuisance by mining organisations, the use of automatic, digital monitoring equipment will reduce the operational costs and provide valuable data for operational decision-making and for designing modifications to the operation.

There are gains to be made in the design of mine WRMS and in their operation. These gains are not evident from the information provided through the returned questionnaires. It is likely that the companies which completed the questionnaire are active in managing all aspects of their mining operation. It is expected that potential gains will become more significant as new regulations governing potential mine-related environmental impacts are imposed on mining companies. New techniques need to be developed to facilitate improved management. Ideally such techniques should require minimum labour and not impose a requirement for specific training.

ACKNOWLEDGEMENTS

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