

GROUNDWATER ASSET MANAGEMENT IN THE MINING INDUSTRY

M Deed¹ and M Preene²

¹Mike Deed, Geoquip Water Solutions Limited
Ipswich, Suffolk, United Kingdom; email: mike@geoquipwatersolutions.com

²Martin Preene, Golder Associates (UK) Limited
Tadcaster, North Yorkshire, United Kingdom; email: mpreene@golder.com

Abstract

Groundwater boreholes are a key element of many mining projects, as part of dewatering and water supply systems, and must achieve high levels of operational efficiency and service availability. Outside of the mining industry, planned borefield maintenance programmes have become a key part of professional well field management, with proven benefits in terms of operational cost savings and continuity of pumping. However, the benefits of proactive planned maintenance of groundwater boreholes on mine sites have only recently been widely recognized.

Potential operational problems are described, including water quality issues which can result in mineral contamination leading to deposits and scale build-up which can clog screens and pumps, reduce water flow and yield, and eventually cause pump breakdowns and mine stoppages. Best practice methodologies to remove or minimise the contamination are described and the benefits of implementing a planned maintenance programme discussed.

Case studies are described from two significant mines in Australia, where boreholes suffered from mineral contamination, including calcium carbonate and iron bacteria contamination. Both mines suffered from increased pump breakdowns, groundwater yields consistently below target and serious cost overruns. Borehole rehabilitation treatment plans were implemented to resolve the immediate contamination problems followed by an ongoing maintenance programme to prevent or minimise their reoccurrence. Treatment programmes included a downhole camera survey, use of a bespoke software programme to review the results of the survey and the available water quality data and a purpose built rehabilitation rig that included the use of specialist chemical treatments to remove and control the existing encrustation and clogging deposits.

1. INTRODUCTION

Groundwater boreholes are a common feature of mine sites. Dewatering systems may involve groups of pumped boreholes, and part of the mine water supply may be from groundwater boreholes, to feed mine camps and process use. In the future, it is also possible that groundwater may be pumped as part of geothermal systems to provide heating and cooling (Digges la Touche and Preene, 2011). Among hydrogeologists and water supply engineers it is well known that over months and years of operation, pumped boreholes may show a gradual reduction in performance, evidenced by loss of yield or increase in drawdown in the wells. The operational problems are often associated with clogging or encrustation of wells or pumps as a result of chemical and bacterial processes occurring in the well (Howsam and Tyrell, 1990).

Outside of the mining industry the need for planned and effective maintenance of groundwater boreholes has long been recognized (Howsam *et al.*, 1995). Water supply companies have identified that groundwater boreholes are fundamental assets of their business, and have widely adapted proactive planned borehole maintenance programmes to replace previous reactive maintenance regimes. On civil engineering projects, dewatering contractors have also recognized the challenges of borehole clogging

and the importance of borehole maintenance (Powrie *et al.*, 1990). Until recently, there has been little focus on performance assessment and planned maintenance of groundwater boreholes on mines sites. This paper will describe how best practice from other industries can be applied on mining projects, in the form of methodologies to manage clogging and encrustation in boreholes, and will outline the benefits of a planned borehole maintenance programme. The challenges and opportunities associated with groundwater boreholes will be illustrated by two case histories from mine sites in Australia.

2. PROBLEMS WITH GROUNDWATER BOREHOLES

Mineral contamination, including iron oxide encrustations, iron bacteria and calcium carbonate, can seriously affect the performance of groundwater boreholes. Iron is one of the most common elements found in nature. It accounts for at least 5% of the earth's crust and most groundwater contains a certain concentration of dissolved iron. Possible reasons for iron bacteria infection include presence of bacteria before a bore is drilled, the introduction of bacteria via contaminated water used during the drilling process or changes in the chemistry of the groundwater, which provides an environment in which bacteria can become established. Whether caused by bacterial activity or through chemical reactions, these types of mineral contamination will eventually affect nearly everyone who sources water from aquifers.

Iron bacteria derive the energy they need by oxidising the soluble ferrous iron (Fe^{2+}) present in the groundwater to an insoluble ferric form (Fe^{3+}). The resultant biofilm is commonly found as a slimy or gelatinous deposit and over time these deposits develop into solid encrustations that can be difficult to remove (Figure 1).



Figure 1. Iron deposits in wells and pumps

Symptoms of biofouling including reduction in the yield of the bore, deterioration of water quality (Figure 2), motor burn out of the submersible pump, and encrustation on the pump, column, bore casing, screens and reticulation systems. Over time the contamination can become so serious that a well has to be decommissioned.

Whilst not as widespread, calcium carbonate contamination causes similar yield and operational problems. When groundwater is extracted via wells there is a natural pressure release on the water as it moves from the formation into the well bore and to the pump. As the pressure drops, the natural carbon dioxide dissolved in solution is released resulting in an increase in water pH. As the pH increases in waters with high levels of calcium carbonates, rapid precipitation of calcareous deposits occur in the well and pump (Figure 3).



Figure 2. Discoloured water associated with pumping from wells suffering from iron deposits



Figure 3. Calcium carbonate deposits

Any sort of contamination or residue build up in water well systems, including iron oxide, iron bacteria and calcium carbonate, can have significant operational implications for the mining industry. Many mine sites rely heavily on groundwater to operate, requiring an almost continual flow. It is used in all steps of the mining process including equipment cooling, dust control, dredging and waste separation. In addition some mines will require extensive dewatering systems, both sub-surface as well and for surface water run off to allow their activities to continue. Encrustation and clogging resulting from residue contamination can lead to a reduction in the yield and bore capacity as well as increased breakdowns affecting production and eventually leading to severe stoppages or mine shutdown. The need for continual flow also impacts on the implementation of scheduled bore and pump maintenance programmes which, if not properly planned, can become limited to a breakdown only basis; consequently underlying but significant contamination problem can fail to be addressed.

There is a range of mechanical, hydro-mechanical and chemical methods that can be employed to rehabilitate boreholes with mineral contamination problems ranging from iron bacteria to residue combinations of oxides and carbonates. A wide variety of chemical products as well as a number of patented commercial treatments is available on the market. Research has shown that chemical rehabilitation can provide to 40 to 60% of the total gain reached during a combined chemical and hydro-mechanical rehabilitation (Houben, 2001). The choice of maintenance method and chemical agent for the dissolution of compounds is critical if maintenance is to be successful. (Deed and Bennett, 2008).

3. ADVANCES IN GROUNDWATER ASSET MANAGEMENT

In recent years there has been an increasing focus on implementing a planned maintenance programme as a key part of professional well field management. The expense of installing new boreholes as well as the licensing, logistics and environmental considerations mean that proactive rather than reactive maintenance has a positive impact both on the bottom line and in terms of sustainability.

The most effective type of maintenance programmes appear to be those that incorporate a monitoring and measuring management plan alongside a regular chemical treatment. One such programme, which has been developed over the last ten years and which incorporates the *BoreSaver* range of treatments, has achieved some notable successes. The goal of the *BoreSaver* borehole management programme is to return borehole production to as close to the original drilled capacity as possible and to help maintain a continual, problem-free water supply.

The *BoreSaver* management programme combines a downhole camera survey with a bespoke software programme that monitors and then analyses a set of key parameters and then benchmarks them against historical data for each well and wellfield, allowing a proactive and individual maintenance plan to be projected. Key thresholds and set points are prescribed to the wellfield, programmed into the monitoring software and then flagged automatically when they occur. A purpose built rehabilitation rig (Figure 4) and *BoreSaver*, a range of approved borehole rehabilitation treatments used successfully in more than fourteen countries worldwide, is used for the necessary maintenance of the wells. These products have been through a rigorous testing and approval process, in the UK and in America. In the UK, *Ultra C*, *Liquid Enhancer* and *IKL Pro* (for calcium carbonate) have been approved by the Secretary of State under Regulation 31 of the Water Supply (Water Quality) Regulations 1989 for use in potable water applications. In the USA, *BoreSaver Ultra C* has been tested and certified by NSF International, the Public Health & Safety Organisation in America, under ANSI/NSF Standard 60 for use in potable water supplies.



Figure 4. Well rehabilitation rig used in *BoreSaver* maintenance programmes

As part of the treatment programme, pre and post treatment CCTV surveys are necessary to allow operators to understand the specific areas in a well that may require attention. They also provide an additional benchmark in the history of the well and its rehabilitation. A high quality, portable, 12 Volt system is preferred for flexibility, ideally with fixed sideview and downview lenses allowing for the close

inspection of a well from different angles (Figure 5). The whole survey should be recorded to a DVD or digital recording device for later review.

One of the most common mineral contamination problems in water wells results from iron oxide and iron bacteria contamination. The chemical treatment applied in these cases is *BoreSaver Ultra C*, a solid with a main active ingredient of oxalic acid dehydrate, with various secondary ingredients (Figure 6). Research has shown that the key component of *BoreSaver* is one of the most effective at dissolving iron contamination (Houben, 2003).

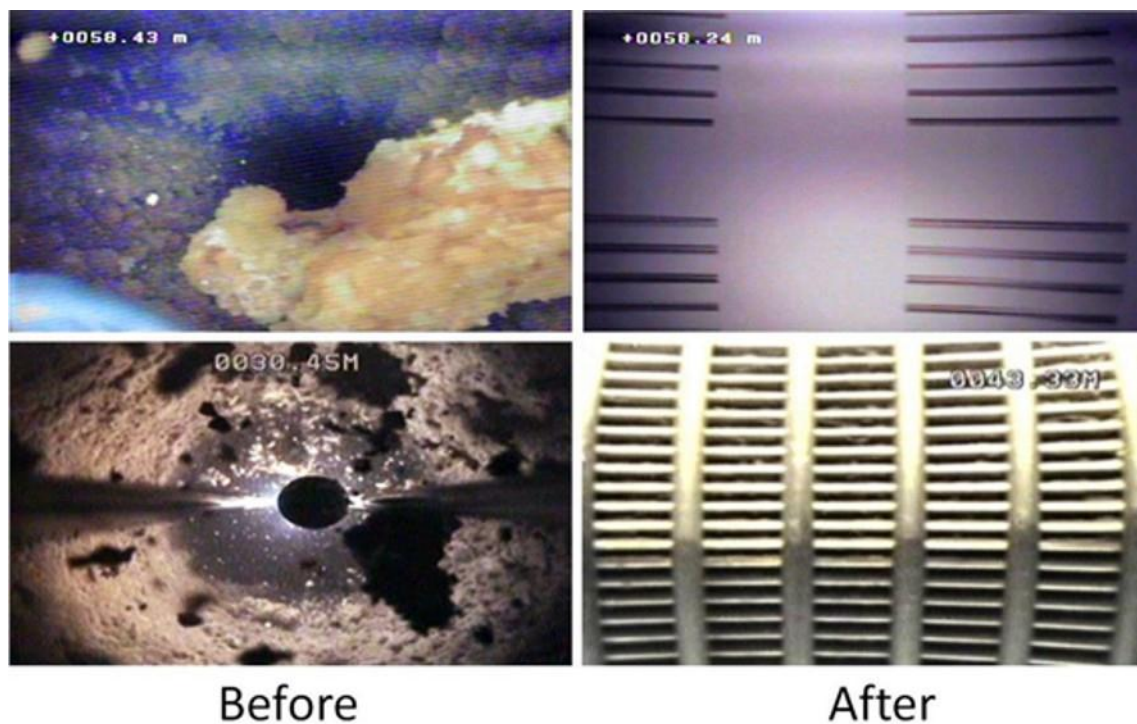


Figure 5. CCTV views of wells before and after treatment

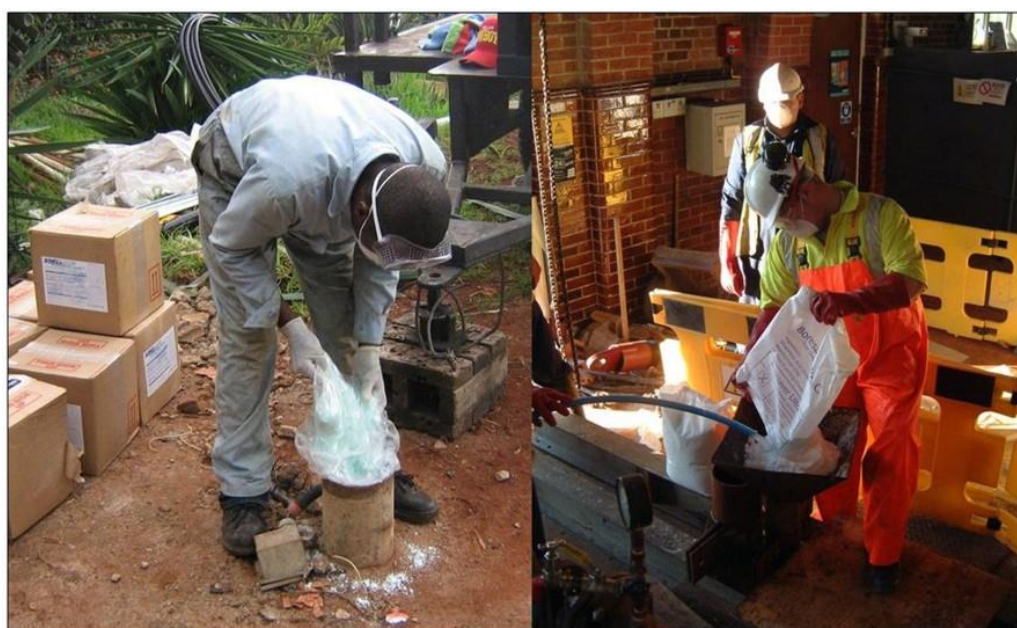


Figure 6. Addition of *BoreSaver* to wells during treatment

BoreSaver Ultra C dissolves and loosens deposits by processes of reduction and complex formation in mildly acidic conditions, and the iron III (insoluble Fe^{3+}) is converted to iron II (soluble Fe^{2+}). By-products of the process are carbon dioxide and water. Residual components of *BoreSaver Ultra C* readily biodegrade to harmless inorganic ions and compounds during the flushing process.

4. CASE HISTORIES

Examples of this approach to well field management are given for two significant mine sites in Australia.

Heavy Mineral Concentrate Mine, Australia

A mine in Western Australia produces more than 700,000 tonnes of heavy mineral concentrate every year and has 24 wells in two separate fields (North and South). The mine utilises water in a range of mining processes and techniques including watering of rehabilitation areas, dust control, and dredging.

In 2008 iron bacteria contamination had started to become a serious problem (Figure 7). Pump breakdowns had increased, groundwater yields were consistently below target and cost overruns were significant. However, the need for continual flow meant bore and pump maintenance was limited to a breakdown only basis.



Figure 7. Iron contamination of pipework and valves on mine site

The mine owners, keen to introduce a proactive rather than reactive maintenance strategy, contracted a team of rehabilitation experts to develop a borehole maintenance and cleaning programme. The goal of the borehole maintenance programme was to return borehole production to as close to the original drilled capacity as possible. The treatment involved the removal of the pump, the cleaning of the borehole and associated plant with a chemical treatment (*BoreSaver Ultra C Pro*) and a purpose built rehabilitation rig (Figure 4) that uses brushing and surging to direct the treatment into the areas where it was most needed.

A detailed site inspection was carried out including a comprehensive downhole camera survey and review of the available water quality data to allow individual assessments to be made on each borehole. The wells were monitored weekly for drawdown and flow rate and these measurements, together with the available historical records, were used to target the worst performing wells and implement an on-going rehabilitation programme, on a planned rotation. As overall system performance improved and flows increased, monitoring moved to every three or four weeks and this has continued for the last four years.

To consider the effects of the maintenance programme, a comparison of the well field performance between 2008 and 2011 has been completed and the benefits have proved to be substantial.

In 2008, a week before the rehabilitation programme started and with all available wells in operation, the yield in the South field was 27,919 m³/week less than their targeted yield (an extraction variation of 46 l/s). Three years on, in 2011, and with half the wells only running part time, almost 15,000m³ more water per week was being extracted, an increase of nearly 50% (Figure 8). By running six of the twelve wells part time, it became a simple process to balance water flows to allow for some wells to be out of service for maintenance without slipping below production targets. As well as reducing maintenance costs, operational costs – particularly power consumption – have been substantially reduced. The pumps are no longer clogged with iron bacteria, can run at peak efficiency and, importantly, breakdown incidents have been reduced to a minimum.

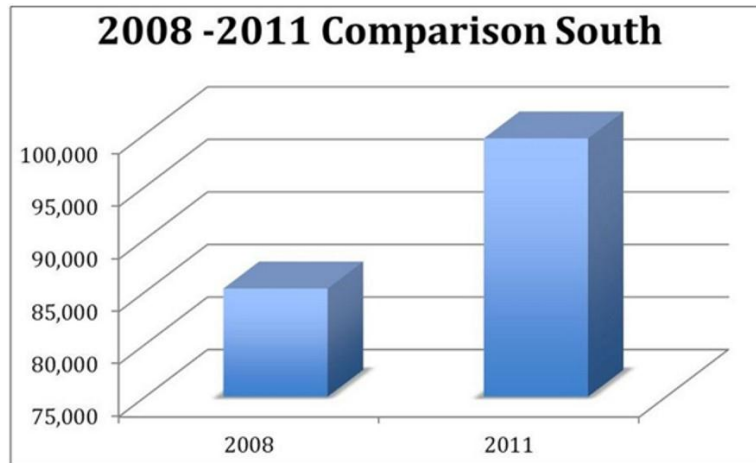


Figure 8. Comparison of water outputs from south well field (m³/week)

The outcome in the north well field was identical to the south – higher water yield at a lower cost and reduced down time (Figure 9). With water production 10,765m³/week higher than in 2008, the mine is now able to run three of the wells on a part time basis, allowing for an ongoing maintenance programme to be implemented without any effect on operational levels.

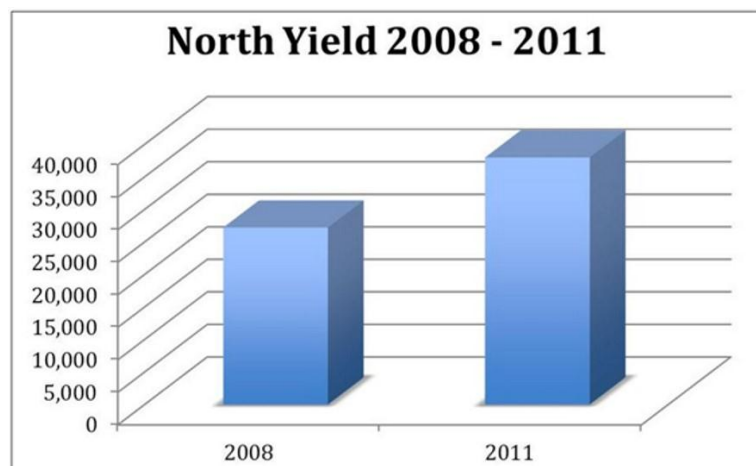


Figure 9. Comparison of water outputs from south well field (m³/week)

Gold Mine, Western Australia

A gold mine in the Great Sandy Desert in Western Australia, 1900 km from Perth, was having problems with calcium carbonate and iron bacteria contamination. The mine used water primarily for ore processing, with other uses being dust suppression, cooling and potable water consumption. Most of the

mine's water comes from groundwater supplies and there are ten aquifers around the mine site used for water abstraction.

Open pit production started in 2004 and underground in 2006. By 2008 there were problems with availability and yield in some of the boreholes as well as regular motor and pump failure. Implementing an ongoing maintenance programme was difficult to achieve without affecting production.

The mine then invited rehabilitation experts to develop a borehole maintenance and cleaning programme for the site. A detailed site inspection was conducted and reviewed alongside a downhole camera survey and the available water quality data to make individual assessments on each borehole. The key issues identified were high levels of dissolved calcium carbonate and some iron bacteria contamination that were compromising the borehole operation (Figure 10).



Figure 10. Iron and calcium contamination in pipework

For the chemical treatment of the system, *BoreSaver IKL Pro* was used, specifically developed for the treatment of calcium carbonate contamination. It is fully and rapidly biodegradable and any product not consumed in the cleaning process turns into carbon dioxide and water on breakdown. The mine owners take their responsibilities to the wider public very seriously and it was important to use a treatment that had a low environmental impact.

The maintenance programme at the mine was initiated in 2009 with the aim of returning borehole production to as close to the original drilled capacity as possible and to have 15% of the borefield available to be taken down for maintenance without affecting production. Initially ten problem boreholes were surveyed and treated, allowing the mine's managers to establish a baseline assessment of the boreholes and their condition. Monitoring showed that the treatment programme completely removed the calcium carbonate contamination and minimised the iron bacteria problems. Both the yields and availability of the ten boreholes had increased. Over the next twelve months the boreholes were monitored and then pulled from production and assessed again. The results from the cleaning were still evident. The yields of the treated boreholes had increased by between 12.5% and 25% and for the first time ever the mine had over 95% of capacity from its well fields and the fewest pump breakdowns on record.

The treatment programme is now part of the mine's borehole maintenance strategy. At the end of 2011, 30 of the boreholes had been cleaned and brushed with vast improvement in availability and yield (Figure 11). The target of 15% of the borefield able to be taken down for maintenance without affecting production had been achieved.

As a result of their work in this field the rehabilitation experts contracted have developed specialist automatic monitoring and datalogging equipment that utilises a bespoke software programme to analyse

the data. It automatically flags key performance indicators to help identify the most appropriate and proactive maintenance programme.

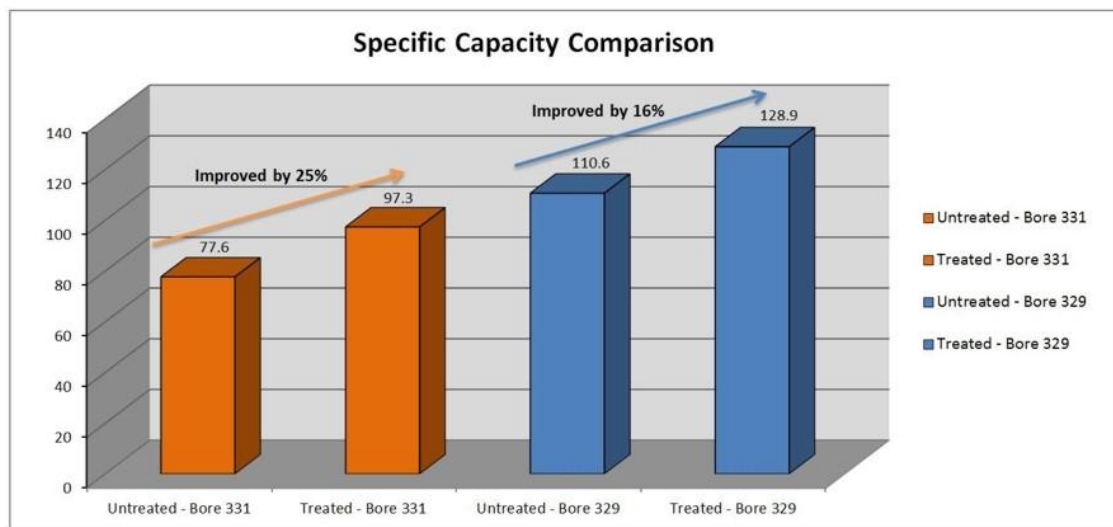


Figure 11. Comparison of specific capacity of treated and untreated bores

5. CONCLUSION

Mine sites need a reliable water supply to operate, and groundwater from on-site well fields is an important component of water supply on many sites. Lessons can be learned from outside of the mining industry, where companies that rely on water supply boreholes for revenue and business continuity have adopted planned and proactive programmes of well field management. Maintenance and management programmes which have been successfully implemented on mine sites comprise elements including downhole camera surveys, use of bespoke software programmes to review survey results and the available water quality data, and a purpose built rehabilitation rig combined with the use of specialist chemical treatments to remove and control the existing encrustation and clogging deposits. Such programmes of well field maintenance have the potential to reduce costs and increase operational efficiency of water supply and groundwater pumping systems on many sites.

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