

Dewatering Bore Pumps – Reducing Costs and Emissions by Maximising Pumping Efficiency Over Time

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ABSTRACT

Pumping water for dewatering and water supply is a major component of electricity consumption at mining operations and hence is a significant contributor of greenhouse gas emissions.

Pump systems at a typical mine site can be broadly split between above ground centrifugal pumps (generally used for water transfer) and submersible borehole pumps (generally for dewatering and/or water supply). In contrast to above ground pumps, submersible borehole pumps can be subjected to varying duty points (total pumping head and flow requirements) as a result of changing bore water levels and yields, particularly in mine dewatering bores. Typically, much higher pumping rates are required at the commencement of dewatering to remove groundwater storage and to intercept sufficient groundwater throughflow to achieve target drawdowns. Once target drawdown levels are reached it often only requires much lower pumping rates to maintain target drawdowns. Pumps sized to remove the large initial volumes of stored groundwater often end up too large for the lower flow rate required for 'maintenance pumping'. This often results in pumps operating inefficiently, a problem which can be made worse when pumps are throttled to reduce the pump output to better match the reduced bore yield.

Current standard operating practice places little emphasis on the electricity consumed by pumps, with the focus often being on minimising capital expenditure ('If it ain't broke don't fix it'). Submersible pumps can have extended service lives of ten to 20+ years. However as the capital cost of a pump typically represents only five per cent of the life cycle cost, the vast majority of the life cycle cost is energy usage.

Through the implementation of a regular review of the operation of borehole pumps, significant reductions in electricity use and associated greenhouse gas emissions can be achieved without impacting the dewatering schedule. In most cases, the capital cost of replacing pumps is more than offset by savings in operating costs. These potential savings become even more significant when considering proposed future carbon tax levies.

This paper presents examples of the opportunities for significant reductions in energy, greenhouse gas emissions and overall costs that can be achieved for a range of dewatering scenarios.

INTRODUCTION

Due to the nature of typical dewatering requirements, higher pumping rates are required at the initial stages of dewatering to remove groundwater storage and to intercept sufficient groundwater through flow to achieve target drawdowns. However, once target drawdown levels are reached it often only requires much lower pumping rates to maintain target drawdowns, typically known as maintenance pumping rates.

As saturated aquifer thickness decreases as a result of the dewatering process, it is common practice to continually 'throttle' the bore pump in an attempt to reduce the pump output to match the decreasing bore yield. Whilst throttling can be achieved by the use of flow control valves or pressure sustaining valves located on the bore headworks, it is more typical to see it achieved by partially closing isolation valves on the bore headworks.

This approach generally works satisfactorily up to a certain point. However, as a pump is throttled back further, it becomes increasingly difficult to maintain a consistent flow rate due to the lack of control in the partially closed valve (ie with a butterfly valve it can be commonly observed that the majority of flow reduction is achieved only when the valve is 75 per cent or greater closed), and as a result the pumps can start to trip out on low flow. The cause of the low flow cut-out can be either due to a lack of sensitivity in the flow switch on the headworks or as a result of the pumping water level in the bore being pulled down to the pump inlet (bore pumping rate is higher than the bore yield). At this point it is common to see dewatering bores being abandoned because they 'ran out of water' or they are pumped only intermittently in response to rising aquifer water levels.

This process may take a number of years depending on the rate of decline of the bore yield, and as a result the required duty point for the dewatering bore pump may move from being efficient to very inefficient – and hence expensive – when throttled back and used as a maintenance water level pump. In the latter stages it also becomes very ineffective as a dewatering bore as it is generally accepted that effective dewatering is better achieved by pumping consistently at lower pumping rates rather than pumping for only one day a week at a higher rate for example.

Submersible pumps can have extended service lives of ten to 20+ years. However as the capital cost of a pump typically represents approximately five per cent of the life cycle cost, the vast majority of the life cycle cost is energy usage. This is consistent with lifecycle costs for centrifugal pumps used by water utilities (Bunn, 2009).

The main focus of this paper is to show that through the implementation of a regular review of the operation of borehole pumps, significant reductions in electricity use and associated greenhouse gas emissions can be achieved without impacting the dewatering schedule. In most cases, an improvement to the dewatering schedule can be seen.

TYPICAL SCENARIO

The calculation of energy savings requires the calculation of the power demand for the existing (and now inefficient) pump at the current duty point followed by calculation of the power demand with a better suited pump and duty point. An example is provided below.

Initial pump operation

The pumps initial duty point is 15 L/s at a total pumping head of 113 m, which is made up of the following: pumping water level of 65 m; friction losses through the bore rising column of 3 m; and a back pressure of 45 m at the headworks. In this example, the actual pressure in the pipeline is 5 m, and the majority of the headworks pressure is as a result of throttling to ensure the pumping rate matches the bore yield.

From the published pump curves, at the above duty point the combined pump/motor efficiency is 44 per cent. This would be considered a low efficiency which is typical of pumps which are throttled back and operating well away from their best efficiency duty point.

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The formula for the power consumption of water with specific gravity of 1.0 is:

$$\text{Power (kW)} = Q \text{ (L/s)} \times H \text{ (m)} \times g \text{ (ms}^{-2}\text{)} / (1000 \times \text{efficiency}) \quad (1)$$

The calculated power consumption based on the above is 38 kW.

Replacement pump operation

Following a review, the above inefficient dewatering bore pump was replaced with a pump better suited to the required duty point. The revised duty point is 15 L/s at a total pumping head of 73 m, which is made up of the following: pumping water level of 65 m; friction losses through the bore rising column of 3 m; and a back pressure of 5 m at the headworks (ie no throttling required).

From the published pump curves, at this duty point the efficiency of the pump is 74 per cent.

Based on the previous calculation shown above, the calculated power consumption is 15 kW. Hence, the power saving through using a better suited pump is 23 kW, or 60 per cent.

As these bores are dewatering bores, they are generally operating around 90 per cent of the time.

The kWh saved in a year can be calculated as follows:

$$\text{Power/year (kWh)} = \text{power (kW)} \times \text{hours/day} \times \text{days/year} \times \text{operating proportion (per cent)} \quad (2)$$

Based on the above, the power/year saved is 180 000 kWh. Assuming a typical mine site power cost of \$0.2/kWhr, the annual saving is \$36 000.

These cost savings increase when a carbon price is applied. The carbon intensity will be dependent on the energy source, however assuming a typical regional gas plant producing one tonne carbon dioxide/MWh the associated emission savings are 180 tonnes/year.

Assuming a \$20/tonne carbon price, this equates to an additional annual saving of \$3600, or a total of almost \$40 000 per annum.

The opportunities to reduce the energy consumption have been evaluated at two Iron Ore mines in Western Australia's Pilbara Region. While the potential savings will vary dependent on a number of factors, the results from these studies provide an indication of the order of magnitude of savings achievable. Costs have been evaluated with and without a carbon price and are presented in absolute dollar amounts as well as payback periods.

Case study one – paleochannel ore deposit (aquifer)

In this case study, the iron ore mine has a large proportion of the orebody below the water table which requires extensive dewatering. Dewatering is primarily achieved through a combination of in-pit and ex-pit dewatering bores with maximum depths of 80 m below ground. The study focused on one pit in a multi-pit operation.

The bores were installed and commissioned between two and three years prior to the review (2005 - 2006, reviewed in late 2008).

A number of the dewatering bores are only operated intermittently. It is accepted practice that as bore yields are declining with time, the pumps equipped for the original bore yields are operated against partially closed valves or 'throttled'. This has the effect of increasing the discharge pressure and consequently reducing the achieved flow rate to a value more consistent with the revised bore yield.

This throttling of the bore has two impacts, increasing energy costs and reducing the reliability of the bore. As discussed previously, as a pump is throttled back further, it becomes increasingly difficult to maintain a consistent flow rate, and as a result the pumps can trip out on low flow. The cause of the low flow cut-out can be either due to a lack of sensitivity in the flow switch on the headworks or as a result of the pumping water level in the bore being pulled down to the pump inlet. At the time of the review, a number of bores were not operational for the above reasons.

The review resulted in the recommendation to change the installed pumps in a number of dewatering bores. Consideration was also given to rotating pumps from other bores in the system that were similarly oversized. In some bores, the original pumps from medium yielding bores were suitable for reuse in the initially larger yielding bores. The bore pump review is summarised in Table 1.

The capital cost and associated energy cost savings are summarised in Table 2.

A power cost of \$0.20/kWh, carbon intensity of 1 t/Mwh and cost of \$20/t has been used. The savings have been evaluated over a two year period. The choice of time to evaluate the savings is relatively arbitrary but serves to illustrate the rapid payback period for these reviews. However in reality, the mine life is ten years and savings will continue well past this two year period.

It can be seen from the above that there is considerable cost savings to be made through the replacement/recycling of the above pumps. Based on a power cost of \$0.20/kWh, for a capital cost of \$91 000 including installation, energy savings of

TABLE 1
Case study 1 – bore summary.

Bore number	Existing pump (kW)	Pump setting depth (m)	Initial flow rate (L/s)	Pumping water level (mbgl)	Proposed pump	Revised flow rate
1	45	73	29	51	No change	29
2	45	73	15	65.3	18.5 kW	10
3	30	73	0	N/A	11 kW	5
4	45	73	15	60.4	30 kW – recycled from bore 3	15
5	45	68	0	N/A	18.5 kW	10
6	55	50	33	38.9	No change	33
7	55	64	0	N/A	37 kW	15
Total			92 L/s			117 L/s

TABLE 2
Case Study 1 - Bore replacement cost savings.

Bore number	Proposed pump	Capital cost (\$)	Remove/install cost (\$)	Energy savings (\$) – over two years. No carbon cost.	Energy savings (\$) – over two years. \$20/t carbon cost.	Overall cost (\$)	Overall cost (\$)
2	18.5 kW	10 000	8000	70 000	77 000	-52 000	-57 000
3	11 kW	Recycled	8000	43 000	47 000	-35 000	-39 000
4	30 kW	15 000	8000	39 000	43 000	-16 000	-20 000
5	18.5 kW	10 000	8000	61 000	67 000	-43 000	-49 000
7	37 kW	16 000	8000	46 000	51 000	-30 000	-35 000
Total		51 000	40 000	259 000	285 000	-168 000	-194 000

approximately \$259 000 can be made. The payback period is eight months. In addition, some of the lower yielding bores can be brought back online, resulting in increased dewatering rates.

Assuming a typical regional gas plant producing one tonne carbon dioxide/MWh the potential emission savings are estimated at 650 tonnes/year.

Case study two – discrete orebody (aquifer)

In this case study, the dewatering of the Marra Mamba orebody is achieved using bores with depths of up to 150 m. The bores considered are all ex-pit bores. As with case study one, after the initial period of dewatering (12 months to two years) water levels in individual bores began to vary widely and a review of the bore performance was undertaken (2008).

As it occurs generally during dewatering, a number of bores experienced reduced yields associated with lower water levels as dewatering has progressed. As a result, pumps had either been removed or throttled back to permit production at lower flow rates. Consistent with case study one, the purchase and installation of smaller, appropriately sized pumps for those bores which have experienced large water level drawdowns represented an opportunity to increase flow rates and significantly reduce energy costs and associated greenhouse gas emissions.

The bores considered for pump replacement and the recommended replacement pumps are summarised in Table 3.

While two of the five bores reviewed were not considered suitable for re-equipping, three bores were recommended to have smaller pumps installed. While these bores yields are significantly reduced from their original yields, they are still valuable in reducing inflow to the pit and reducing the hydraulic head at the pit wall. The recommended pumps have low capital costs, maximise the achievable flow and reduce energy costs.

The payback period for the replacement of the larger pump is less than three months.

Assuming a typical regional gas plant producing one tonne carbon dioxide/MWh the associated emission savings by re-equipping the one bore are estimated at 380 tonnes/year.

OTHER CONSIDERATIONS

Use of variable speed drives

An alternative to rotating pumps is to use variable speed drives (VSD). Variable speed drives permit the variation of the pump performance by varying the frequency of power supplied to the motor and consequently the speed of the motor and hence pump. As a result of varying the pump speed, the pump performance varies. Varying the speed of the pump results in a proportional change in flow, while the head produced varies proportional to the speed raised to the power two. While the use of VSD is well suited to some applications, there are a number of associated disadvantages to their use in dewatering applications including:

- capital cost of the VSD;
- dependent on climate, VSD may require installation in air-conditioning, further increasing costs;
- the use of a VSD results in an efficiency loss;
- operation across the range of expected duty points while maintaining efficiency may not be achievable; and
- repairs to VSD can require specialist expertise which can result in difficulties with on-site maintenance.

A recent study of four major US water utilities showed that many of the of the VSD pump installations operated less efficiently than was the case for installations consisting of fixed speed pump stations (Bunn, 2009).

TABLE 3
Case study 2 – review of installed bore pumps.

Bore	Current pump	Current flow	Comment	New flow	Selected pump	Capital cost	Remove/install cost	Energy saving no carbon cost	Energy saving \$20/t carbon cost
1	No pump	0 L/s	Low yielding water level has now declined such that bore is not optional. Not recommended for re-equipping.	-	-	-	-		-
2	No pump	0 L/s	As above.	-	-	-	-		-
3	55 kW	5 L/s	Although low yielding, pump operation required to lower head on pit access ramp.	8 L/s	11 kW	\$8 000	\$8 000	\$77 000/year	\$85 000/year
4	No pump	0 L/s	To be re-equipped with smaller pump.	12 L/s	22 kW	\$11 000	\$8 000	-	-
5	No pump	0 L/s	To be re-equipped with smaller pump.	12 L/s	22 kW	\$11 000	\$8 000	-	-
Total		5 L/s		32 L/s					

It is the author's experience that the use of VSD is generally not practical for mine dewatering bores and it is not considered in further detail in this paper.

Provision of pump capacity for flood events

Whilst yields from dewatering bores typically decline with time, rainfall or stream flow events may increase the available short term bore yield. Depending on the specifics of the deposit to be dewatered there may be the requirement to maintain standby capacity to provide for these events. Any revision of pump capacities should be undertaken together with a hydrogeological review to ensure that the replacement of initial pumps with smaller pumps does not compromise pit dewatering. Pump selections should be made in conjunction with hydrogeological advice as to the likely range of water levels to maximise pump efficiency and production across the expected range of operating conditions. In areas where a number of bores have experienced reduced yields, a smaller more efficient pump could be installed in some bores for maintenance dewatering whilst the original larger pump could be retained for operation in response to storm events only.

Well efficiency

Further savings in pumping costs could be achieved by regular review of well efficiency by conducting pump tests to compare initial well efficiency against current well efficiency. This could provide an early warning of the slotted and screened sections of bore casing becoming clogged and resulting in decreased yields or lower pumping water levels. However, this issue is outside the scope of this paper and is not considered further.

SUMMARY

Through the implementation of a regular review of the operation of borehole pumps, significant reductions in electricity use and associated greenhouse gas emissions can be achieved without impacting the dewatering schedule. In most cases, the capital cost of replacing pumps is more than offset by savings in

operating costs. These potential savings become even more significant when considering proposed future carbon tax levels. A review every six to 12 months period dependent on the rate of change of groundwater levels is considered appropriate.

An additional improvement which can be achieved through a regular review is that the dewatering rate can actually be increased. This increase can typically be achieved by installing smaller pumps in bores. Whilst these bores are no longer able to achieve the initial rates of dewatering, they can generally be used for lesser 'maintenance' pumping rates.

The opportunities to reduce the energy consumption has been evaluated at two Iron Ore mines in Western Australia's Pilbara Region. The case studies confirm that there is considerable gain to be achieved through the regular review of installed dewatering bores. Typically across a dewatering borefield, some bores will be suitable for ongoing operation with the original pumps, some will be suited for replacement with smaller pumps while others will not be suitable for continued production. The case studies showed that payback periods of three months to eight months are achievable and that the replacement not only reduces operating costs but can also increase dewatering rates.

As pumping costs are a major component of electricity demand and hence operating costs, the potentially savings are in the range of tens to hundreds of thousands of dollars.

Reductions in carbon dioxide emissions in the order of several hundred tonnes/year are readily achievable. As a comparison, a typical car produces approximately four tonnes of carbon dioxide/year.

However, the review of dewatering pumps requires a cross disciplined approach comprising hydraulic engineers and hydrogeologists to ensure that the minimisation of pumping costs and associated greenhouse gas emissions is achieved in tandem with maximising dewatering production.

REFERENCES

- Bunn, S, 2009. Operating pumps to maximize efficiency, *Water*, June, pp 44-51.