Dewatering at Western No. 7 Colliery

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ABSTRACT

Deep mining in the Collie Basin has suffered with high levels of water flow and sediment in-rushes throughout its 90 year history. Current day experience in working conventional bord and pillar by mainly mechanised means is that advance to the dip is impeded at about the 150m depth of cover by excessive water flow and pressure bursts.

Extensive analysis of exploration borehole data and reconstruction of depositional environments helped define important hydrogeological characteristics of roof and floor aquifers, aquitards and aquicludes. Hydraulic parameters were estimated with some accuracy using indirect methods, and later confirmed by pump testing.

Groundwater flow modelling showed that mine scheduling would have to be a balance between down dip and lateral development if aquifer pressure heads were to be decreased to suitable levels. Since pressure reduction in aquifers immediately above and below the mine opening was identified as the key aim in groundwater control, a series of trial in-pit dewatering holes were installed, and demonstrated pressure heads could be reduced at rates compatible with a mine extraction sequence which, in turn, controlled the rate of down dip mine advance.

A case history of the successful application of in-pit dewatering systems within difficult hydrological conditions for mining is described, with emphasis on the close collaboration required between hydrologists, mine planners and operations personnel.

INTRODUCTION

Western No.7 Colliery forms one of three underground mines and two open-cuts operated by Western Collieries Limited in the Collie Basin situated about 200km SSE of Perth, Western Australia.

Groundwater problems in the Collie Basin have impeded deep mine development over many decades. Such problems are accentuated at Western No.7 Colliery more than at any other operating underground mine in the Basin because of the presence of extensive aquifers and generally relatively thin, weak roof and floor aquitards. Groundwater and potential sediment inflows in deep workings has been instrumental in limiting mining to first workings, from which a low, overall recovery of 35% is achieved. Consequently groundwater has to be managed, at an optimum level, taking into account both economics and safety.

Hydrological studies (as a part of complete geotechnical investigations) were initiated for Western No.7 Colliery to:-

- define the position of roof and floor aquifers with respect to the working section;
- determine the aquifer properties and characteristics;
- use the aquifer properties and characteristics to predict likely effects of the aquifers on mining conditions;
- prepare strategies to manage and control groundwater impacts.

The methodology adopted to meet the study objectives included:-

- installation of piezometers to measure aquifer characteristics and pressure heads on the coal seam;
- pump testing and monitoring of a trial advance dewatering bore to confirm aquifer properties, distribution and extent;
- in-mine investigations to correlate mining conditions with mine water make and installation of in-pit dewatering holes to study depressurisation responses;
- computer modelling to predict total volumes of water to be handled from depressurisation/dewatering operations and to determine the balance between in-pit and advance dewatering requirements as a guide to mine planning;
- laboratory testing of cored samples of aquifers to determine physical properties of the aquifers (e.g. porosity, permeability and particle size distribution);
- assessment of geophysical logs.

AQUIFER CHARACTERISTICS

Geological Description of Aquifers

The Collieburn No.2 Seam is mined in Western No.7 Colliery and associates with roof and floor aquifers consisting mainly of medium to coarse grained, cross-bedded, feldspathic and quartzose sandstones. Some pebble and grit horizons occur and a few large pebbles of well-rounded quartz are scattered throughout the aquifers. The sandstones are basically hard and stiff, but delithified zones do exist, probably due to secondary chemical processes.

The aquitards are composed of the fine grained materials, such as shale, siltstone and laminite, with the coal seams generally behaving as aquicludes. All hydrogeological units dip conformably with coal seams at about 8 degrees to the southwest.

Hydrogeology

The sandstones between the overlying Wyvern Seam and the Collieburn No.2 Seam form the roof aquifer. Within the sandstone body are lenses of shale, siltstone and laminite beds and minor coal that subdivides the interburden into two sub-aquifers.

Hydraulic connections between upper and lower roof aquifers was unknown, but recognised as an important component in modelling roof hydrogeology for mine planning. The overall roof aquifer varies in thickness from about 22 metres in the west to about 39 metres near the centre of the proposed mine area.

From sparse exploration data it is generally believed that the Collieburn No.2 Seam floor aquifer is about 8 metres thick (during exploration most of the cored holes just penetrated the floor sandstones before being terminated).

The Collieburn No.2 Seam roof aquitard consists of a lateral and vertical variation of cannel coal, shale, mudstone, claystone, siltstone and laminite with some thin sandstone beds in the working roof. The roof aquitard varies in thickness from about 5 metres to less than 1 metre.

The Collieburn No.2 Seam floor aquitard consists of the same variety of rock types as the roof aquitard with the exception of cannel coal. The floor aquitard varies in thickness from less than 2 metres to zero where the floor aquifer comes into contact with the seam base.

The Collieburn No.2 Seam acts as the aquiclude between the roof and floor aquifers and varies in thickness from about 1.8 metres to about 3.5 metres.

Early Estimates - Hydraulic Parameters

Particle size analyses on recovered core samples indicated that aquifers would dewater sufficiently quickly by gravity drainage to allow normal methods of dewatering (production bores, in-pit holes and mining induced drainage) to be utilised.

Using the effective grain size, D_{10}, (Hazen's approximation) [1] from particle size distributions and experience, the hydraulic conductivity of the Collieburn No.2 Seam roof and floor aquifers was estimated to be about 4m/d. Similarly, based on particle size analysis and experience, a value of 1×10^{-4} was used for storage coefficient and specific yield was taken as 15-20%. [2]

Likely areas of recharge occur where the Collieburn No.2 Seam subcrops (particularly where the Collie River South Branch passes over the top of the crop lines), the old Collieburn open-cut and the nearby flooded Scottish Colliery. Piezometric information indicates that there is a general flow of water from a topographic high in the west towards the mine.

The total volume of water contained in the Collieburn No.2 Seam roof and floor aquifers within the proposed mine area is of the order of $100 \times 10^6 m^3$.

HYDROLOGICAL INVESTIGATIONS

Piezometer Monitoring

The majority of piezometers in the Western No.7 area were installed in HQ size cored holes drilled during exploration programmes. Some larger diameter multiple piezometers were also installed and provided information on the floor aquifer as well as at different heights in the roof aquifer.

Pre-mining piezometric water levels in the current mine area were 172m R.L. and 170m R.L. for the Collieburn No.2 Seam floor and roof aquifers respectively. The lowest piezometric water levels over the mine to date are 95m R.L. for the floor aquifer and 110m R.L. for the roof aquifer at a current depth of cover of about 100m.

Water levels are generally monitored on a monthly basis but more frequently if rapid changes are brought about by mining operations. The data gathered is stored on computer and presented visually to operations personnel as hydrographs of pressure head (generally) relative to the seam.

Pump Testing and Advance Dewatering Monitoring

The location for a trial advance dewatering bore was chosen by Western Collieries Limited and Australian Groundwater Consultants from considerations of facies maps, mine plans and surface features.

The site selected was a compromise between short-term immediate benefits to mining and long-term regional benefits, being about one kilometre down the proposed main dip headings from the then extent of mine development.

After construction and developing of the bore to a depth of 148.4m with 12 metres of screens in the lower roof aquifer and 6 metres in the floor aquifer, a multi-rate test was performed. From results of the multi-rate test it was decided to operate the constant rate test at about 1 000m^3/d for four days. [3]

Pump test results confirmed previously estimated aquifer hydraulic conductivities of 5m/d and storage coefficients of about 1×10^{-4}. Also no hydrogeological boundaries were encountered during pump testing and the upper part of the roof aquifer was found to be hydraulically connected to the lower part despite being separated by a 4 metre thick shale bed in the test site area. [3]

Results further indicated that the trial advance dewatering bore (PB20) would be capable of operating at a discharge rate of 1 700m^3/d against a head of 120 metres and producing a drawdown of 73 metres (at the pump site) after one year of pumping. [3]

Results of the pump test and subsequent advance dewatering from the pump well showed that one bore would not be sufficient to adequately depressurise/dewater the roof and floor aquifers surrounding the Collieburn No.2 Seam.

Additional depressurisation would be required to advance the main dip headings down towards PB20 area (and beyond to over 200 metres depth of cover) and it was thought that this additional depressurisation could be achieved by installing in-pit dewatering holes as mining advanced, provided mine sump bore capacity was large enough to accommodate the water produced. Subsequently, Australian Groundwater Consultants were commissioned to model the roof and floor aquifers with a view to predicting pressure heads and water discharge volumes over a 10 year mine development period.

In-mine Investigations

In-mine investigations centred around mapping inflow rates and installation of three in-pit dewatering holes to study depressurisation responses.

A Jacro 105 skid-mounted drill was used to install the in-pit dewatering holes. Firstly a 100mm diameter hole was drilled in the aquitard (so as to just penetrate the aquifer) to accommodate a 65mm ID PVC stand pipe. The stand pipe was then grouted into the hole by pumping cement slurry into the annulus until cement returned out of the PVC pipe. The cement was allowed to set overnight and then a 50mm diameter hole was drilled on through the stand pipe into the aquifer (to a depth of about 15 metres for the roof aquifer and about 5 metres for the floor aquifer). Once the hole was finished a gate valve was fitted to the stand pipe to control the flow of water and allow pressure head readings to be measured.

Mapping results showed that most of the uncontrolled water make from the roof came from falls. The three major roof falls to date all occurred before proper implementation of in-pit dewatering. Somewhat less water is made from roof fractures and drippers account for the remainder of uncontrolled roof inflows.

Water make from the floor is a far more prevalent and wide-spread phenomenon than water make from the working roof. Water make in the floor occurs in the form of sudden bursts or ruptures (caused by machines mining too deep into the floor aquitard) which flow freely at first and gradually diminish with time.

Depressurisation responses of the inital three roof in-pit dewatering holes were encouraging and the need to know whether this technique could be applied at depth and throughout the whole proposed mine area was recognised.

GROUNDWATER CONTROL

Mine Planning Criteria and Dewatering Strategy

Recent experience in the Basin saw advance of dip-headings restricted to about 150m depth of cover due to excessive in-rushes and associated instability. Development of Western No.7 Colliery planned a main dip heading advance to 200m depth of cover with laterals extending to 2km either side.

Options available to mine planners were:-

(i) develop main headings to maximum depth of cover, then develop laterals at depth and extract production panels on the retreat, or

(ii) balance development of main dip headings and laterals, gradually working to the dip with the effect of delaying commencement of extraction from production panels.

Geotechnical analysis of heading and intersection stability showed that water pressure in the immediate roof of less than 20m head was required for acceptable stability. This limitation arises from the ability of water pressure to work roof strata partly dilated as a result of changes in the pre-mining stress regime about the openings.

Since stability of workings was dependent on reduction in hydrostatic pressures about workings, and not on volume of inflows, the aim of dewatering strategies was to create a halo of reduced aquifer pressure about the workings. The advantage in this approach was that groundwater control could be concentrated in a much reduced volume of aquifer, with the expectation for lower groundwater control costs.

This was clearly demonstrated for radial dewatering holes installed from the workings compared to the much higher capital and operating costs associated with advance dewatering bores installed from the surface.

However, it remained to be proven whether sufficient depressurisation would be achieved within the overall development and extraction schedules available to mine planners.

Mine Scheduling and Dewatering Modelling

The viability of mine schedules associated with the first option (or Schedule No.1) was dependent on adequate rates of depressurisation of the roof and floor aquifer being achieved relative to rate of dip heading advance.

To assist in evaluating system requirements and performance, Australian Groundwater Consultants were commissioned to model the roof and floor aquifers with a view to predicting pressure heads and water discharge volumes over a 10 year development period for Schedule No.1. The consultants were required to adhere to the criteria of maintaining the pressure heads below about 20 metres over the scheduled mine workings.

The proposed rapid advancement of the main dip headings were predicted, by the modelling, to run into areas where the in-pit dewatering could not reduce the pressure head in the roof aquifer to below about 40 metres. The rapid rate of advance of the working faces would not allow sufficient time to extract the required quantities of water. [4]

A new mine plan (Schedule No.2) was produced, based on a balance of down dip and lateral development. The consultants remodelled the new mine schedule, which proved to be generally satisfactory in respect of pressure heads and Schedule No.2 was adopted as the mine plan for Western No.7 Colliery. [4]

Computer modelling predicted that the total daily water make would gradually rise from 5 000m^3/d in 1985 to a maximum of 14 000m^3/d in 1989 and then decline to about 7 000m^3/d in 1995. The predicted total volume of water produced to year 1995 would be 37 x $10^6 m^3$ of which about 85% comes from the roof aquifer.

From computer modelling results and an average discharge rate of about 400m^3/d (for each in-pit dewatering hole) it was estimated that the number of new in-pit holes to be drilled each year reaches a maximum of 36 in 1989 and thus a new hole is required no more frequently than every sixth working day.

Design requirements indicated that installation of in-pit dewatering holes should not be too great a burden on mine resources (labour, power, equipment) and the concept of in-pit dewatering was proven feasible as regards number of holes and spacing required.

Management of Total Mine Water

The total volume of water produced by the mine will be handled by a succession of six sump bores located down the main dip headings with up to four being in use at any one time.

The deeper sump bores will need to be equipped with multistage pumps to handle heads from 100-200 metres and their capacities such that they operate for a maximum of twelve hours per day.

The water pumped by the sump bores can be disposed of into the South Branch of the Collie River via settling ponds to keep suspended solids levels below statutory limits.

Water produced in the various mining panels can either gravity drain to the sump bores or be handled by large portable pumps (e.g. 20kW Flygt 2151). Naturally, small pumps (e.g. 2.2kW Flygt 2066) will be required at each down dipping working face to pump water to the larger panel pumps for eventual disposal via the system of sump bores.

Actual Mine Pumpage and Degree of Dewatering

Mining conditions experienced during initial dewatering and to date have shown that stable underground openings at Western No.7 Colliery can be achieved under roof aquifer pressure heads of 30 metres (rather than the 20 metres head used in computer modelling) because of the highly successful implementation of roof bolting.

Consequently, considerably less water than predicted has been pumped. In fact the volume of water actually pumped is about 60% of the volume predicted. Also, at 30 metres head some sections of the roof aquifer may still be essentially confined (albeit almost totally depressurised) and thus only the 'elastic' water has needed to be released to bring about significant depressurisation. The bulk of the dewatering then, takes place up-dip of mining advance. Penetration of only the lower part of the roof aquifer during installation of in-pit dewatering holes has meant that satisfactory depressurisation can be achieved with minimal extraction of water.

Roof aquifer pressure heads have been maintained at or below 30 metres during mine development by the installation of in-pit dewatering holes at points compatible with operational activities (e.g. end of a belt extension, a cut-through etc.) and areas of roof instability.

Floor aquifer pressures have been maintained at about 15 metres below that of the roof by sporadic outbursts of water through the thin aquitard veneer (generally caused by mining activities).

To date, some 28 in-pit dewatering holes have been installed into the roof aquifer and 3 into the floor aquifer. Currently 16 holes are still producing significant quantities of water.

Monthly monitoring of pressure heads from within the mine and monitoring of water levels from surface piezometers is used to control the desired degree of depressurisation and installation of required in-pit dewatering holes.

To date, dewatering has taken place at the rate of about one metre head per month (within the mine area) with an initial depressurisation of about five metres head upon installation of an in-pit dewatering hole (at that point).

Currently, about 75% of the water pumped from the mine is produced from in-pit dewatering holes. This good degree of controlled water entry into the mine allows for easier scheduling of pump maintenance and replacement, as the in-pit holes can be turned off to facilitate the solution and rectification of any operational problems.

The success of in-pit dewatering at Western No.7 Colliery as a means of producing stable underground openings in conjunction with a balance of down dip and lateral development has meant that mining by total extraction techniques can be planned for and carried out in up dip panels to aid in the overall profitability of the mine.

REFERENCES

[1] FREEZE, R.A. and CHERRY, J.A. Groundwater, p350, Pretence-Hall, New Jersey (1979)

[2] AUSTRALIAN GROUNDWATER CONSULTANTS PTY. LTD., Report No. 1 Western 7 Dewatering, p2, (Nov. 1984) - unpublished

[3] AUSTRALIAN GROUNDWATER CONSULTANTS PTY. LTD., Report No. 2 on Western 7 Dewatering PB20 Construction and Testing, (May 1985) - unpublished

[4] AUSTRALIAN GROUNDWATER CONSULTANTS PTY. LTD., Predictive Numerical Modelling of Western 7 Dewatering, (Oct. 1985) - unpublished