Conclusions from using an active production well for mine drawdown compliance

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Abstract

Groundwater use from Wellfield B in the Great Artesian Basin (GAB) is regulated according to the regional effect on aquifer pressure. Drawdown assessment criteria (allowing a maximum of 5 m as pressure drawdown measured in piezometers) were set at five sites, including two active pastoral production wells. The monitoring of active production wells is not ideal but is sometimes a practical compromise, and the influence of pastoral abstraction was considered to be minimal by allowing the wells a predetermined recovery time prior to measurement.

Pastoral flow was eliminated in one of the wells in 2009/10, providing an opportunity to assess whether antecedent flow had affected the reported apparent drawdowns. 'Jackboot Bore' is 503 m deep with measured wellhead pressures between 60 and 70 m water (expressed as the height of water column) above ground level. The flow-out temperature of the water has been around 50°C.

A methodology has been developed to incorporate the influence of temperature on groundwater head and drawdown. Results indicate a sharp contrast between the reported apparent drawdown in mid-2009 of over 4 m and the revised temperature-inclusive drawdown of 1 m. The high importance of the wellfield for mining and town water supply, and the compliance based management regime based on a maximum drawdown criterion of 5 m, means that there is an unacceptably large uncertainty in drawdown estimation in this case.

Results also indicate that, while flowing, impractical recovery times in the order of months would have been required for Jackboot Bore. Hence the use of an active production well for assessing compliance with drawdown criteria is not recommended practice in the GAB.

Keywords: Great Artesian Basin, Australia, groundwater head, pressure, drawdown

Introduction

The Great Artesian Basin (GAB, Figure 1) is a large artesian basin situated beneath the arid interior of Australia and is, in most places, the sole source of reliable drinking and livestock water. The main aquifers are sandstones of Jurassic age that are up to 2 km deep.

Wellfield B (Figure 2) supplies an average of 30 ML/day of groundwater from the GAB to the Olympic Dam mine and to the town of Roxby Downs in South Australia (SA). Water use from Wellfield B is regulated by drawdown criteria (maximum of 5 m as pressure drawdown) set at five sites to preserve flows at GAB springs and pressure at pastoral wells. The monitoring network includes both dedicated monitoring sites (28 in 2011) and pastoral wells (26). The monitoring of private wells near Wellfield B serves to expand the monitoring network and to confirm that artesian pressures are preserved in pastoral wells.

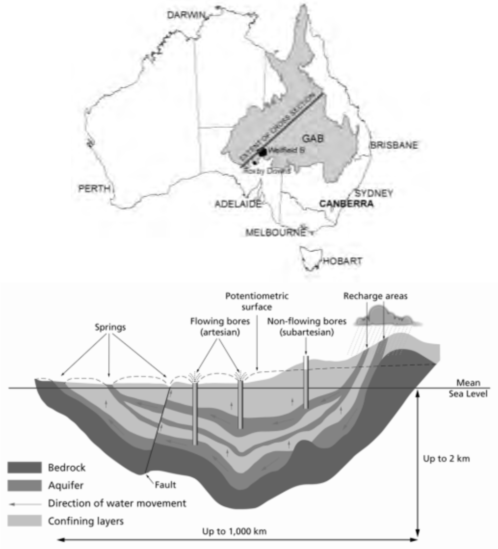

Figure 1 *The Great Artesian Basin of Australia (cross-section from http://www.gabcc.org.au)*

Methods

To measure pressure, most GAB wells are shut in and surface pressure is measured after a predetermined wait/recovery time. Drawdown is calculated as the difference between the contemporary pressure and an agreed reference pressure judged to pre-date any effects of Olympic Dam water supply abstractions.

The use of existing and privately owned wells in monitoring networks is widespread. In the early stages of groundwater development, monitoring programmes often rely on measurements in private wells (Jousma and Roelofsen, 2004). Privately owned wells even play important roles in several current national monitoring programmes (Jørgensen and Stockmarr 2008; Jousma and Roelofsen 2004; Taylor and Alley 2001). The monitoring of active production wells is not ideal but is sometimes a practical compromise. The influence of abstraction from the production well itself may be minimised by allowing the well to recover prior to measurements (Jousma and Roelofsen 2004) or by continuous monitoring and subsequent filtering of the data.

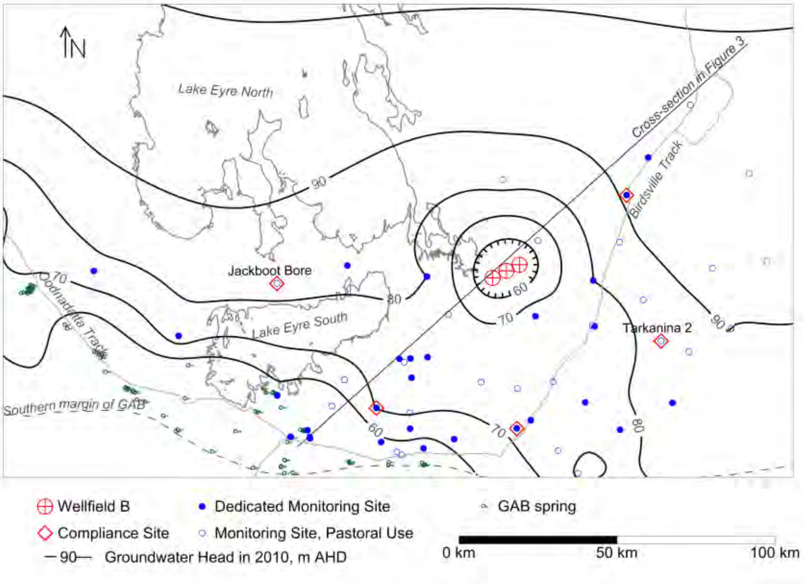

Figure 2 *Wellfield B, monitoring and compliance sites*

Jackboot Bore

In this paper, we focus on the analysis and reinterpretation of data from one of the compliance sites, Jackboot Bore. Measured wellhead pressures vary between 600 and 700 kPa (60 to 70 m H_2O) and the flow-out temperature of the water around 50 ºC. Prior to December 2009, the shut-in pressure (SIP) was measured after a 30 minute recovery time, considered sufficiently long to minimise the influence of antecedent pastoral abstraction.

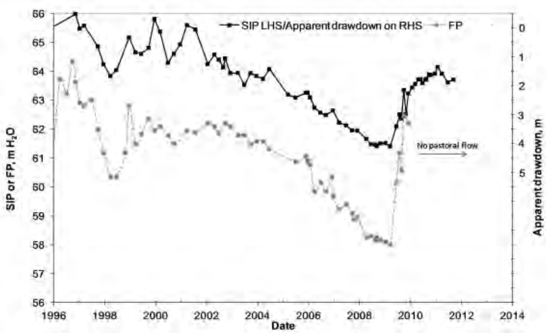

Figure 3 *Shut-in Pressure (SIP), Flow Pressure (FP) and Apparent Drawdown in Jackboot Bore*

As Figure 3 indicates, despite the 30 minutes recovery period, antecedent flow must have affected the measured SIP, and, as a result, the apparent drawdown significantly. This conclusion has been reached because, since mid-2009 when the pastoral abstraction decreased and was eventually eliminated, the SIP has increased by approximately 2.5 m (24 kPa). The 2.5 m increase in SIP is significant, especially when compared to the maximum compliance drawdown of 5 m. The pattern and timing of the increase in SIP also appears to be inconsistent with a distant wellfield operating at 70 km distance at reasonably constant rates since 1996.

Groundwater Head and Wellhead Pressure

Both groundwater head and wellhead pressure follow well-defined processes in ordinary artesian wells (containing cold and fresh groundwater): flow from the well cause both wellhead pressure and head to decline; conversely, when a well is shut in, both the pressure and head increase. In hot and deep artesian wells wellhead pressure changes with temperature and therefore the pattern for wellhead pressure in ordinary artesian wells is not followed. Hence a methodology was developed to calculate temperature-inclusive head:

$$H(T) = E - D + P_w/\rho_f g + \Sigma(\rho_i(T_i) \times b_i)/\rho_f \text{ and } \Sigma b_i = D \qquad (1)$$

where H(T) is the temperature-inclusive head, E is the elevation (at the reference, normally wellhead or ground level), D is the depth of the bore, P_w is the wellhead pressure measured at the reference for reference density ρ_f (normally freshwater), g is the gravitational acceleration. $\rho_i(T_i)$ is the density of the i-th discretised layer with temperature T_i and thickness b_i.

Equation 1 allows the re-interpretation of drawdown at Jackboot Bore. As Figure 4 indicates, the recovery of head from pastoral flow took more than one year. Pressure recovery was smaller and slower. While the overall pattern of recovery appears to be similar to that expected for cold aquifers, there is a difference in Figure 4 between the early parts of the solid black line, representing the recovery in cold aquifers, and that of the temperature-inclusive head. The solid black line represents an estimate using the widely used Cooper-Jacob (Freeze and Cherry 1979) approximation for confined aquifers after 45 years of pumping at 2.5 L/sec (216 ML/day) and a transmissivity of 40 m^2/day, and matches the latter part of the head recovery since 2011 reasonably well.

The Cooper-Jacob method suggests that 5 months are needed to achieve a recovery of approximately 2 m. In reality, it took nearly one year for the temperature-inclusive head to recover 2 m, and one and a half years for the pressure to recover.

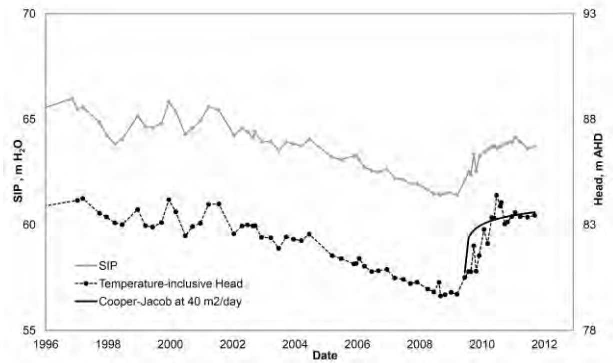

Figure 4 *Shut-in Pressure (SIP) and Temperature-inclusive Head*

Analysis of Results

Figure 5 shows the revised temperature-inclusive drawdown in Jackboot Bore using an estimated 84.5 m AHD reference head. Current temperature-inclusive drawdown is estimated as approximately 1 m. For comparison, the apparent drawdown (from Figure 5; based on pressures only) is also shown. There has been a gradually increasing departure between shut-in and flow pressures between 2002 and 2009 (Figure 3) and the difference between those can be used as a proxy for pastoral use. It is therefore suggested that pastoral flow increased sometime around 2002. If so, using the standard 30 minutes recovery time allowed for less drawdown recovery (leaving more residual drawdown) and caused the apparent steep increase in drawdown. The remoteness of Jackboot Bore and the quarterly monitoring did not permit the detection of small changes in flow.

Figure 5 illustrates interpreted drawdowns since 1996. Neither the temperature-inclusive, nor the pressure-only based drawdown patterns are consistent with Wellfield B operating at its 70 km distance from Jackboot Bore and at reasonably constant rates since 1996. Hence a 'correct' or most likely drawdown pattern representing our best estimate, is also shown in Figure 5. In drawing this interpretation of the correct drawdown pattern, we considered the few local maxima prior to 2002 and the late 2010 data as correct and disregarded data between 2002 and 2010.

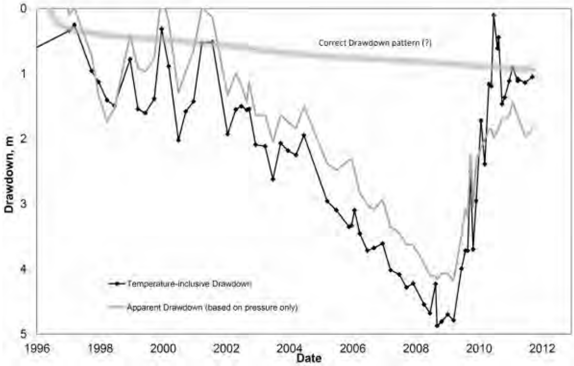

Figure 5 *Shut-in Pressure (SIP) and Temperature-inclusive Head*

Conclusions

There is a sharp contrast between the reported drawdown in mid-2009 of over 4 m and the revised drawdown of 1 m. The importance of the wellfield for mining and the town water supply, and the compliance based management regime based on a maximum drawdown criterion of 5 m, means that there is an unacceptably large uncertainty in drawdown estimation in this case. The use of this active production well for compliance has not been successful. Such reliance on production wells for compliance monitoring is not recommended in this hydrogeological environment.

Using short and standard recovery times for monitoring an active production well is problematic even in ordinary cold and freshwater hydrogeological settings. The data obtained in this way are not adequate for compliance monitoring because minute changes in flow rate may significantly influence the early, steep part of the pressure recovery. As a consequence, small variations in flow (or well hydraulics) in the production well may be falsely attributed to drawdown from another well or a wellfield.

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