Coal mining and the Liverpool Plains: Aquifers and aquitards

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Dr Wendy Timms, Consultant Senior Engineer-Scientist, UNSW Water Research Laboratory
Professor Ian Acworth, Gary Johnston Chair of Water Management at UNSW.

Aquifers used for irrigation are frequently embedded in clay rich sediments known as aquitards. These aquitards are low permeability units that dominate the large volume of alluvial sediments on the Liverpool Plains. Aquitards can act as a 'barrier' to groundwater flow.

Understanding aquifers and aquitards typically requires 'muddy' investigation work in the paddock in addition to desk top or computer studies. Investigations can be relatively expensive because of the need to drill test holes. Investigation 'tools' used by the Water Research Laboratory include state-of-the-art geophysical logging techniques, aquifer hydraulic testing, geotechnical and chemical analysis of sediment cores, intensive automated monitoring of groundwater levels and water quality studies. Realistic computer models of flow and contaminant transport are then developed to assess various management scenarios.

A combination of these investigative tools have been applied as required at sites around the Caroona area including Claremont, Yarramanbah, Hudson, Connamara, Pullaming, Breeza, Native Dog Gully and at several spring sites west and south of Lake Goran.

Understanding of local groundwater processes commenced with work by George Gates (1980) and progressed during the early 1990's through a number of catchment 'snapshot' studies: Broughton (1994); the Liverpool Plains Water Quality Project (Timms 1997; Mawhinney 1998); Lavitt (1998); Coram (1999); the CSIRO team (Stauffacher et al. 1997; Dawes et al. 2000). In the last 10 years, work by Acworth and Timms at the UNSW Water Research Laboratory has further progressed our understanding and has been of international interest.

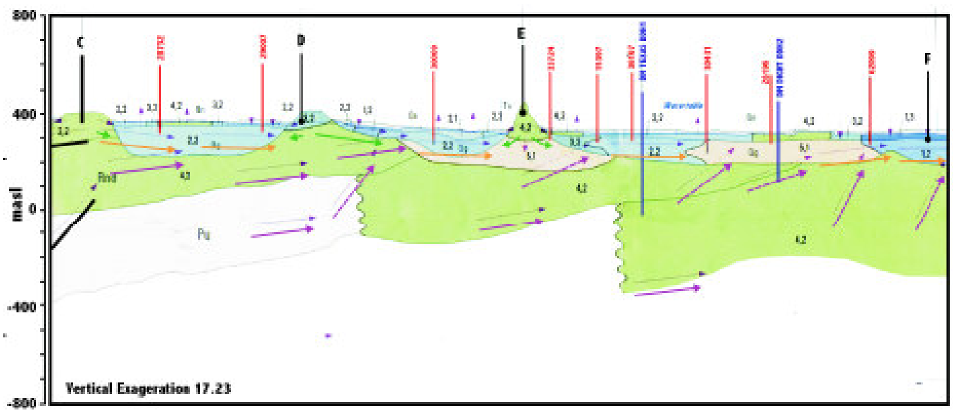

Figure 1. Inferred groundwater flow from bedrock to alluvium (Broughton 1994). There are currently very few groundwater monitoring bores in bedrock so hydraulic connections are uncertain.

The work by WRL has shown that aquitards play a hitherto unappreciated role in the groundwater system.

- Significant leakage can occur through thick aquitard units down into underlying aquifers,
- leakage through aquitards can positively contribute to recharge and groundwater balance
- drying and cracking of aquitards releases stored salt to shallow groundwater and creeks
- aquitards have negligible permeability if kept saturated
- consolidation or settlement in the order of centimeters and metres can occur with dewatering or drying of clay aquitards.

Alluvial sediments include both clays (aquitards) and sands and gravels (aquifers) and mixed sediments. High yielding aquifers in the Liverpool Plains are found in sand and gravel lenses. These lenses can be thought of as old river beds that weave their way through finer grained mud deposits. They are therefore variable in thickness and prone to rapidly change direction. This conceptual model is in contrast to the rather simple layer or blanket type aquifer deposits often incorporated in groundwater models. The Gunnedah Formation is an unofficial geological title sometimes given to the deepest, thickest deposit of gravel and sand.

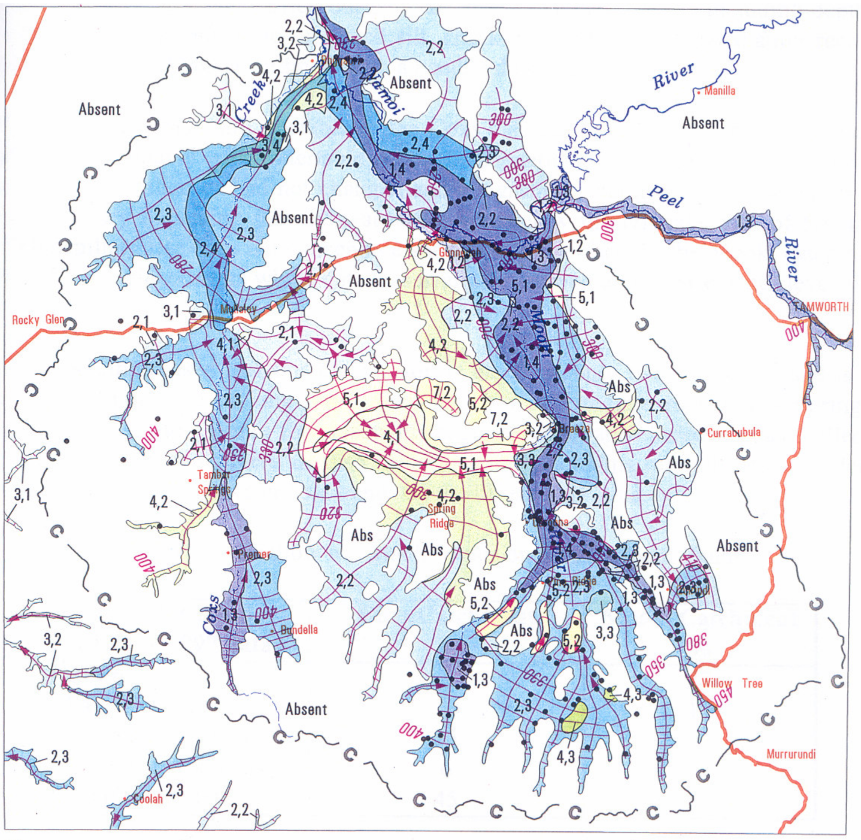

Figure 2. Hydrogeological map showing the high yielding alluvial aquifers (Broughton 1994, updated in 1997 by Timms).

There are substantial high yield/low salinity aquifers east of the Mooki River at 90m to 130m below the land surface. Recharge of these aquifers is from a combination of diffuse infiltration on the footslopes of the surrounding hills, infiltration from gravel outcrops in stream beds, and from leakage through the clay strata underlying the floodplain.

Groundwater flow is naturally to the north and west, flowing from high pressure to low pressure (usually downhill). In the area of alluvium east of Caroona, flow rates have been estimated to be of the order of 2m to 10m per annum. Flows (and flow rates) are constricted at the Breeza gap, and the high levels of extraction between Breeza and Carroll/Gunnedah have resulted in a reversal of groundwater flow direction in the north of the area, such that groundwater is now believed to flow south from the Namoi. Groundwater age, measured by various isotopes, is of the order of tens of thousands of years. This means that current pumping may be mining the aquifer! Falling groundwater levels are clearly seen at some sites (Fig. 3).

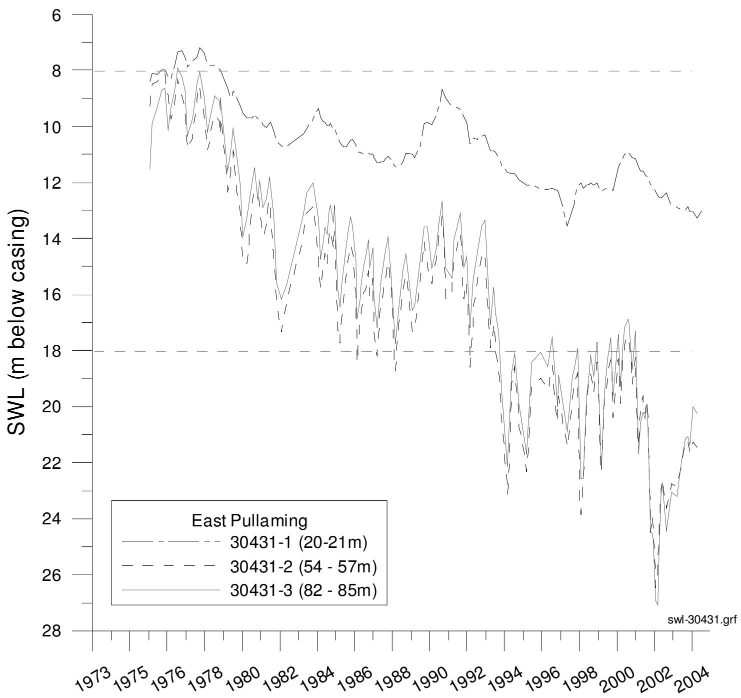

Figure 3. Groundwater level declines since the 1970's at a monitoring site near Breeza (Timms and Acworth, 2006).

Changes to aquitards can result in increased transmissivity or leakage. Aquitards will leak more when they are:

- Thin;
- Dried & cracked, even non-visible cracks;
- Not homogeneous in the clay composition; and
- Subject to lowered groundwater levels.

The leakage through the aquifer can be beneficial to management, for example, if it counteracts rising saline groundwater, but it can also increase the vulnerability of the aquifers to contamination

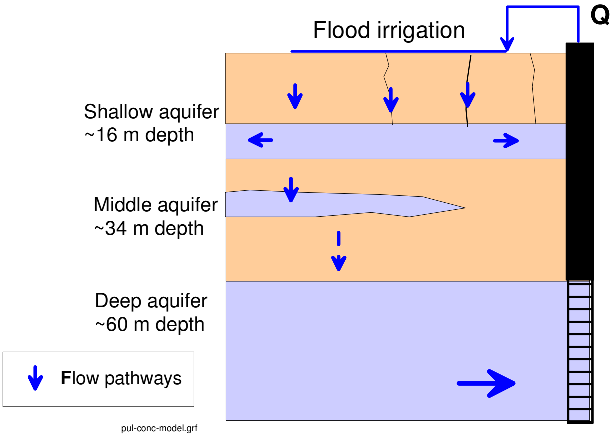

Figure 4. Induced groundwater recharge due to leakage through cracked clays at an irrigation site.

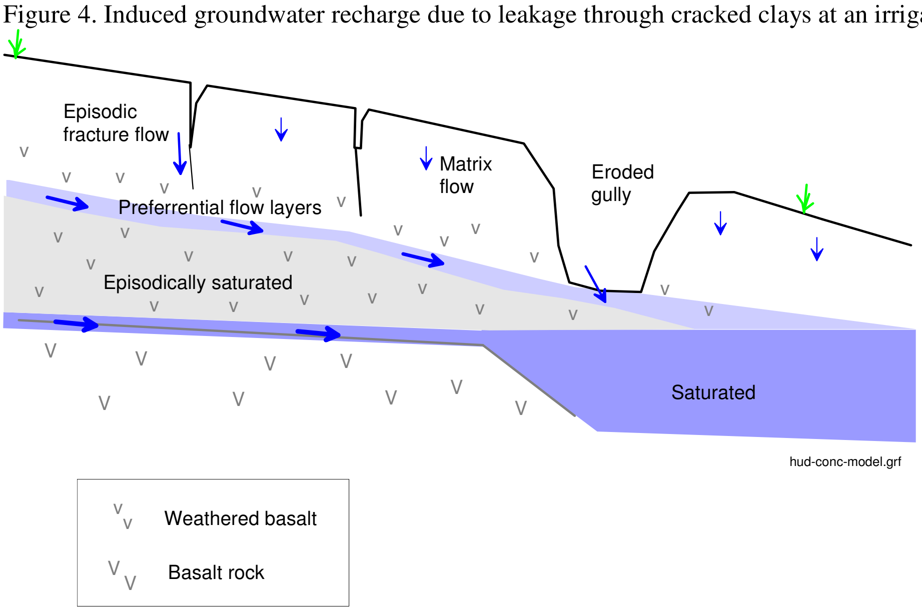

Figure 5. Hudson footslope - recharge through weathered basalt hill slopes near the Liverpool Ranges.

Weathered basalt slopes and drainage channels are found near the Liverpool Ranges where most recharge occurs to the alluvial aquifers (Fig. 5). However, the hydrogeology of these slopes is very different to sandstone hill slopes. Sandstone hill slopes found at Pine Ridge, Spring Ridge, and near Caroona are not as important to recharge. For example, at one sandstone hill slope, monitoring and investigation found that groundwater levels were lower under the ridge than on the plains and that almost no recharge occurred. Rainfall on the sandstone ridges appears to be lost mainly to evaporation with minor runoff. However, further investigation is needed to confirm this.

Salt has been accumulated in the soil and clay aquitards over tens of thousands of years by wet and dry deposition. Deep clay cores have shown that only about 10% to 20% of total salts is stored in the upper 3m to 6 m depth where it is detected by soil surveys. There is also evidence of saline playa lakes in the sediments, suggesting that Lake Goran may be the remnant of a larger salt lake system. Erosion of these sediments, or release of salts by drying and increased flushing, will have implications for achieving river salinity targets downstream. Proposed mining activity must therefore be planned to minimize or eliminate the release of additional salt to the surface drainage system.

Recent work has caused a re-think of conceptual models describing groundwater flow and discharge in valleys south of Caroona (Timms and Acworth, 2006, 2005). In this case, new field data was used in a computer model of flow and contaminant transport to show that salt has diffused downwards through a 30 m thick aquitard over at least ten thousand years. The very low permeability of clay below the surface cracked and fractured zone, combined with almost no hydraulic gradient means that upward discharge of water is extremely slow with water possibly moving only about 5m in 10,000 years. This means that the clays can effectively become barriers if used appropriately.

The increased weight of moisture in the soil zone causes water pressure changes deep within the compressible clay even though no physical recharge occurred. A small increase of groundwater levels in the gravel aquifer at 50 m depth, confined by the clay aquitard was observed about 70 days after rainfall increased storage weight near the ground surface. Groundwater hydrographs need to be re-examined in the light of this finding because a rise in the hydrograph has previously been taken to imply direct downward movement of groundwater.

Work by UNSW-WRL has shown that salinisation is not due to discharge and evaporative concentration of fresh groundwater from deep aquifers. Instead, the evidence indicates that shallow and deep groundwater systems are often poorly connected (Timms and Acworth, 2005, 2006). Clay-rich sediments must be managed to prevent release of salts that have been deposited and accumulated over geological time.

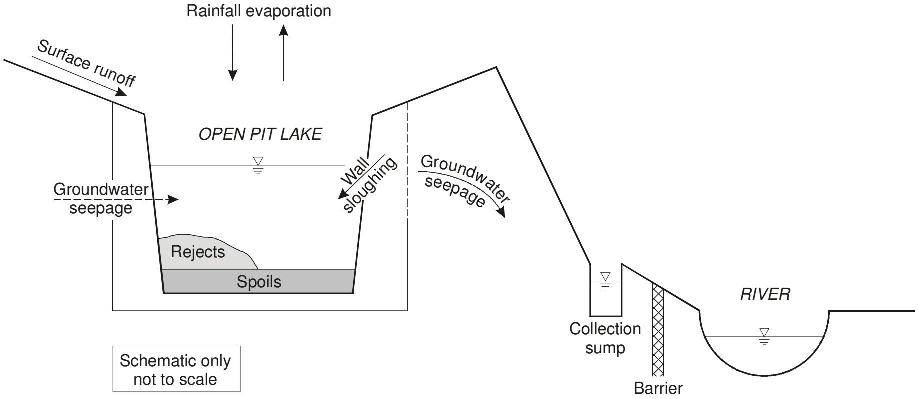

Figure 6. Schematic representation of water management at an open cut mine.

Knowledge about groundwater can be utilised in forward planning for mine management, mine closure and mine rehabilitation. The geochemical reaction of water (groundwater or rainfall) with mine spoils and rejects can produce contaminants. After mining, salt can be concentrated by evaporation in pit lakes that are left behind. Non-permeable barriers can be constructed to prevent leakage of contaminants through alluvium to rivers and streams. Alternatively, it may be possible to utilize buffer zones of natural clay aquitards as a barrier between mining and rivers or alluvial aquifers.

Based on the extensive research that has been carried out in the past 10 years, we believe that coal mining on the Liverpool Plains will impact on the groundwater system used for irrigation, stock and domestic use if mining is carried out beneath the flat-lying plains. Management strategies on the Liverpool Plains are currently addressing the adverse impacts that irrigation development has had on the groundwater system. If coal mining is to proceed, the additional impacts on groundwater recharge, groundwater levels and water quality will require careful investigation and management.

If surface and shallow mining activity were to be confined to the ridges and/or clay dominated areas, then it seems that agriculture and mining could coexist if the mining development is carefully engineered. Based on our current understanding, the main groundwater issues related to coal mining are likely to include:

1. Alluvial aquifers
   - changing recharge balance, interaction with underlying rock aquifers
   - extent of pressure change in confined aquifers
   - water quality draining from coal seams and the overburden
   - interactions with bedrock (including sandstone and coal measures) is uncertain
2. Clay aquitards
   - utilising natural & engineered clay barriers
   - drying & release of salts during dewatering
   - settlement of ground surface, consolidation of sediments
3. Water quality in pit lakes & mine voids
   - saline sinks, evaporative concentration of salts
   - forward planning for closure and rehabilitation of mine sites

The relative size and impacts of proposed mine sites should be considered in the regional context of environmental and socio-economic factors. A transparent process of regulatory checks and approvals together with peer-review by suitably experienced professionals is recommended.