The Potential for Artificial Recharge of the Tertiary Aquifers of the Latrobe Valley Depression, Victoria, Australia

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Abstract: The Latrobe Valley has an extensive monitoring network to measure the environmental impacts of mining and power generation operations. Regional groundwater and topographic survey data have been recorded for over 40 years. This data is used to calibrate mathematical models for the prediction of groundwater drawdown and subsidence. The concept of artificially recharging aquifers through re-injection of aquifer water adjacent to or beneath worked out mines is currently being evaluated. Artificial recharge could result in reduced operational costs as well as a reduction or potential reversal of the groundwater related environmental effects of coal mining. This paper explores the potential for artificial recharge using groundwater-modeling techniques.

Keywords: Groundwater re-injection, Subsidence, Lignite, Mining, Environment

1 INTRODUCTION

The Latrobe Valley (LV) occurs approximately 150 km east of Melbourne in the state of Victoria. It occupies the western and onshore portion of the Gippsland sedimentary basin. The Gippsland Basin contains approximately 40% of Australia’s fossil fuel reserves in the form of offshore oil and gas fields and onshore coal deposits. In addition, the Basin contains significant groundwater resources and zones that have the potential to be developed for geothermal energy.

Since the commencement of mining operations in the early 1920’s, some 1500 million tonnes of coal and 850 million m$^3$ of groundwater has been removed from aquifer systems within the LV Depression. The groundwater is extracted to maintain mine stability and close monitoring of groundwater pressures within each mine ensures groundwater extraction is minimised. The extracted water has been primarily returned to the surface water system but more recently it has also been utilised in the cooling process associated with electricity generation in the adjacent power stations.

Regional monitoring and groundwater database management are vital components in the assessment and management of the environmental impacts of coal mining. In the LV, an extensive monitoring network is used to measure land surface and groundwater levels. This data is used to calibrate mathematical models for the prediction of groundwater drawdown and subsidence.

The LV Power Generators are also continuously seeking ways to reduce operational costs and improve overall performance. Recent controlled reductions in flow rates as a result of optimisation of groundwater depressurisation systems have already resulted in benefits to groundwater levels.
adjacent to the Mine (Schaeffer et al 1999). This study investigates the feasibility of artificial recharge of aquifers, which could further raise potentiometric pressures in certain parts of the mines, where high pressure levels do not currently pose a serious risk to mine or personnel safety.

1.1 Regional Impacts

Monitoring of observation bores and survey points throughout the LV over the last 40 years has indicated the environmental impacts of aquifer depressurisation within the mines consists of:

- Falling Water Levels within and beyond the mines
- Settlement within and beyond the mines and
- Changes in water quality.

Of these the most significant impact has been the reduction in groundwater levels and the associated settlement. Aquifer depressurisation has lowered regional groundwater levels for some distance beyond the mining district. This together with other groundwater extractors within central Gippsland contributes to regional subsidence.

Potentiometric levels have been reduced by up to 120m and cumulative settlements in the order of 2m have occurred adjacent to mining operations (Figure 1). This magnitude of settlement is centred around the mines and reduces to less than 50mm, 25 to 50 km away from the mines where groundwater levels have reduced by 20 to 30m since commencement of mining operations. Based on previous subsidence studies (Newcomb et al 2000) and regular regional subsidence leveling surveys, it is predicted that subsidence will continue to occur in response to ongoing depressurisation of the regional aquifers. **The subsidence is greatest adjacent to the existing mines**

where these is a combination of maximum aquifer pressure reduction and thick coal seams at shallow depth.

![Figure 1: Regional Subsidence Contours](image)

2 REGIONAL HYDROGEOLOGY

Three major aquifer systems separated by less permeable zones (aquitards) consisting of coals, clays and silts have been recognised throughout the LV (Schaeffer et al 1998). The qualifying word "system" is used to emphasise that rarely does one aquifer exist; rather, numerous sand, gravel and basalt sequences of varying thickness, lateral extent and interconnection occur. These are interbedded with coal, clay, silt and weathered basalt units. Furthermore, within individual sand beds, there is a high degree of heterogeneity and anisotropy.
The aquifer and groundwater systems in the LV are very complex in terms of lithologic variability, hydraulic properties and groundwater flow. Some aquifers extend over large areas, and, partly through complex structures, into the offshore part of the Gippsland Basin. Other aquifers are only of local extent.

Figure 2 shows a schematic hydrogeological cross-section from Yallourn East Field Mine through Hazelwood Mine and eastward to the Loy Yang Power Mine defining the major aquifers within the LV Mining area. These aquifers represent the Shallow (SAS), Morwell Formation (MFAS) and Traralgon Formation Aquifer Systems (TFAS) in the western part of the Gippsland Basin. Recharge to these aquifers is considered to be mainly along the Strzelecki Ranges and to a lesser degree along the northern and southern Basin margins. Recharge is also thought to occur along the crest of the Baragwanath Anticline (eastern part of Latrobe Valley) and through relatively fresh zones of basalt and associated sands of the Morwell and Traralgon Formations where these units subcrop in the west of the Basin (Brumley et al 1982). Under natural conditions groundwater flow is easterly along the LV away from the recharge areas and discharges to the lateral marine units east of Rosedale.

Figure 2: Schematic Hydrogeological Section Yallourn East Field - Hazelwood - Loy Yang

3 SURFACE AND GROUNDWATER BALANCE

To maintain stable operating conditions approximately 28 Mm$^3$ of groundwater was extracted from the 3 operating mines in the LV during 2000. Of the total extracted 16 Mm$^3$ of groundwater was utilised in the power station cooling cycle. The remainder was used to supplement fire protection and mine water supply systems. The utilisation of groundwater in the power generation and mining operations is currently the highest beneficial use practical for groundwater beneath the LV mines.

The total water usage for 2000 in the Latrobe Power Industry from the regional water resource was 88 Mm$^3$, being both river water and groundwater. In any discussion on the re-injection of groundwater, it must be made clear that this will be done at the expense of surface water. At the Loy Yang and Hazelwood sites this would result in an increase of surface water utilisation of approximately 5 and 11 Mm$^3$ respectively.
3.1 Other Groundwater Users

Although the LV mines are major extractors of groundwater, other industry within the region also utilises groundwater from the regional aquifer systems. These other users include the city of Sale, Rosedale Tannery, Longford gas plant, and local irrigators. Groundwater is also extracted as part of oil production off the Gippsland coast. Based on previous estimates (Walker & Mollica, 1990) the Latrobe Valley mines contribute to approximately 25 to 30% of the total groundwater extracted from the regional aquifer systems. This proportion is likely to remain relatively consistent into the future, although some mines may increase while others may decrease their groundwater extraction. Through artificial recharge, the LV power companies would reduce regional groundwater extraction and settlement whilst contributing to the sustainable use of the groundwater resource.

4 ENVIRONMENTAL IMPACT

4.1 Falling Water Levels

Prior to groundwater extraction in the LV, groundwater pressures in the confined aquifer systems were under artesian conditions, with groundwater flow in an easterly direction to the Gippsland Coast. In areas where the aquifers subcrop they generally discharged groundwater to the surface water system. As groundwater pressures have significantly declined in some parts of the Gippsland Basin, some of the previous discharge points are now providing recharge locations to the groundwater system. This reduces the contribution of groundwater to surface water and, particularly in times of drought, results in reduced surface water flows.

4.2 Ground Settlement

Regional variations in the rates and magnitudes of subsidence to date have been relatively modest with no incidents of discrete movements across faults and other geological discontinuities. Differential subsidence is however resulting in gradual tilting of the land surface. The impact of this is primarily on rivers and creeks as well as surface drainage across the relatively flat land surface.

Changes in stream gradients can be relatively detrimental. Increases in gradient will increase water velocity, which can result in erosion of streambeds, while decreases in river gradient can reduce water flow velocity resulting in siltation of streambeds. Both phenomena have the potential to impact on and change the stream environments. In addition tilting of the land surface can change surface gradients sufficiently to interrupt surface drainage systems. This could result in formation of poorly draining areas, which can limit productivity of local farms.

5 POTENTIAL FOR ARTIFICIAL RECHARGE

As the LV mines deepen, significant energy (and cost) is required to pump groundwater to the surface. The perception of the regional impacts of the mining operations is also gaining a higher public profile. Through artificial recharge, possibly using existing bores for aquifer re-injection, the perceived benefits include:

- reduced operational costs,
- stabilisation of regional groundwater pressures,
- reduction in subsidence rates and
- demonstration of the power industry’s commitment to good environmental management

It is considered that, due to its higher transmissivity, the TFAS (Figure 2) is a potential target for re-injection trials. Sites within or external to the mines would be suitable.

To evaluate the potential for groundwater re-injection in the LV, the Loy Yang Power Mine (LYPM) was used as a case study. The mine could either inject water generated at its own site or

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inject aquifer water from nearby mines as part of a co-operative approach to minimise the regional impact of mine site aquifer depressurisation.

6 CONCEPTUAL MODELLING

A MODFLOW (MacDonald and Harbaugh, 1988) based groundwater model consisting of 3500 cells (70x50 mesh with 100m x 100m cells) has been used for preliminary investigation of recharge well operation near LYP Mine.

The hydrogeology in the mine model is represented by defining six layers for aquifers representing the MFAS & TFAS and vertical leakage components for the intermediate aquitard layers. The boundary conditions for this model were derived from a regional model. The mine model was calibrated using historic pumping rates and piezometric levels around the mine area.

To evaluate the impact of recharge wells, a four-year period was modeled using 4 existing discharge wells and three conceptual recharge wells, located east of the mine. Twenty-five percent of water removed from the TFAS at LYPMI was recharged through well points into the TFAS at selected locations north east of the mine area. The model predicts that recharge wells significantly improve the groundwater potentials in the north east area close to the recharging wells. There is also a reduced impact on groundwater potentials in the mine area where the discharging wells operate. Contours of changes in groundwater potentials for the TFAS aquifer between the case when both the recharging and discharging wells are operating and the case when only discharging wells are operating at the end of the four year simulation period are shown in Figure 5.

![Figure 3. Improvement of Groundwater Potentials in TFAS due to Recharge Wells](image)

7 REGULATORY COMPLIANCE

The State Environment Protection Policy, (SEPP 1997) indicates that groundwater may be re-injected into aquifers as long as the relevant protection agency is satisfied water quality falls within the same segment and does not have a negative impact on the beneficial use of the groundwater by other users. As all groundwater extracted from the Latrobe Valley mines currently falls within Segments A1 and A2 (suitable for all uses), re-injection of groundwater, is likely to be approved. In addition, as much of the treated mine water discharged into the Latrobe River System also falls within the same water quality segment, it is also feasible that treated mine water could be re-injected into the groundwater system. This water however may have slightly higher TDS and particulate matter, which may result in screen clogging and maintenance issues.
8 DISCUSSION AND CONCLUSIONS

In order to maintain mine stability the LV mines need to extract groundwater from artesian aquifers beneath the mine. This groundwater is currently utilised in the cooling cycle for the Hazelwood and Loy Yang power stations prior to being treated and discharged into the Latrobe River system.

A review of water quality requirements and preliminary modeling indicate that it is technically feasible to re-inject groundwater extracted from beneath Loy Yang Power Mine into the same aquifers east of the mining operations. The modeling also suggests that as little as 25% of total extracted groundwater re-injected would result in significant impact on water levels to the east of the mine. In addition it is also feasible that mine water once treated may have acceptable qualities for use in artificial recharge of aquifer systems in the Latrobe Valley.

As the hydraulic properties of aquifers beneath other LV mines are similar to those at Loy Yang, artificial recharge through aquifer re-injection could also be feasible at all LV mine-sites.

The Latrobe Valley Power Industry, through a CRC research project will continue investigations into the long-term viability of artificial recharge. Future investigations will concentrate on:

- the development of a regional groundwater model,
- the impact of re-injection on the overall water balance,
- the economic viability of replacing groundwater now currently utilised in the power generation cycle with surface water against the risk of mine stability,
- other sources of water for injection, such as waste water from new coal drying technologies
- operational issues, such as fouling and clogging, associated with sustainable injection and
- the public perception of the environmental impacts of falling water levels and regional settlement induced by mining activities in the LV.

This conceptual study has shown that a modest re-injection program could increase groundwater pressures outside the immediate mining areas and therefore potentially reduce or halt the associated regional subsidence. It is therefore predicted that a re-injection program as modeled will potentially result in minor changes to the overall site water balance, which may produce an improved environmental outcome.

REFERENCES


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