Requirements and Constraints for Sustainable Shallow Groundwater Pumping for Salinity Control in Irrigated Areas

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ABSTRACT

Many irrigation areas are facing the problems of high watertables and soil salinity. This paper shows how generalised assessment can be made of the drainage requirement as well as the assessment of the drainage timing. For the case study area (Coleambally Irrigation Area) this showed a requirement of 0.25 –0.5 ML/ha/yr over the past ten years. Assessment of where drainage is required can be undertaken by analysis of the spatial distribution of the groundwater mound and depth to watertable. Whether reuse is possible or disposal is required depends upon the groundwater salinity. Using these assessments the target areas for pumping can be determined. The fact that whether groundwater pumping can occur or not, depends upon the presence of adequate shallow aquifers. Analysis of the Coleambally area found that the potential areas for pumping were not evenly distributed. This requires planning to ensure those areas that cannot undertake pumping are not adversely affected by those that do. This is likely to occur if the water pumped is disposed of into irrigation or drainage channels. In the area studied in Coleambally the areas most likely to have potential for groundwater pumping were at the head end of irrigation channels and the areas least likely to be able to implement pumping on the tail end. This means that area wide planning is required before any sort of drainage is implemented to ensure the productivity and sustainability of all areas in an equitable fashion.

INTRODUCTION

In the Riverine plains the aquifer system consists of three formations (Figure 1). The top layer, which extends from the surface to about 70 m deep, is known as the Shepparton formation. It consists of a matrix of clay, silt and silty clay, with lenses of fine to coarse sand and gravel. Due to differences in hydraulic properties within the Shepparton formation, it has been further subdivided into two layers. The upper layer, roughly the top 20 m is known as the Upper Shepparton (US) and the lower layer is known as the Lower Shepparton (LS). The transmissivity of aquifers in the Shepparton formation is very low and varies in the range of 10-500 m^2/day. The formation below the Shepparton formation is known as the Calivil formation. It extends between 70-130 m from the surface and comprises extensive sand and gravel layers interspersed by kaolin-type clay layers. The deepest aquifer layer at 130-200 m is known as the Olney or Renmark formation. It consists of extensive sand and gravel deposits with layers of lignites.

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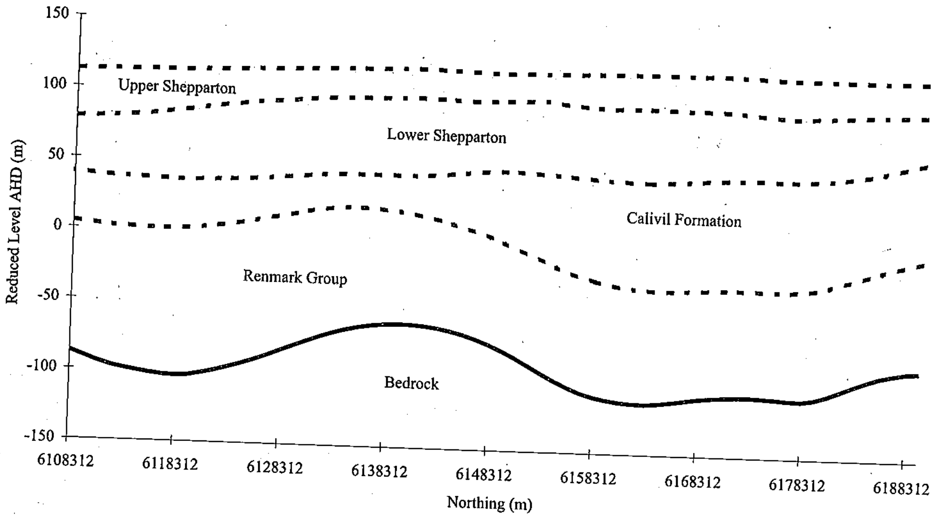
Figure 1: North to south transect through Easting 396348(m)



The deeper aquifers (Calivil and Renmark formations) have high transmissivities in the order of 1000-3000 m^2/day. Private pumping by irrigators have established that good salinity groundwater, <0.5 dS/m, exists in these deeper aquifers. There may also be reasonable quality water available in shallow aquifers (Shepparton formations), which have not been previously assessed. Shallow groundwater pumping is important for the following reasons:

6. Scenario analysis using groundwater model of the Coleambally Irrigation Area (Prasad et al. 2001) and the Coleambally deep bore project (Lawson and van der Lelij 1992) have shown that there is little drawdown in shallow aquifers due to pumping from the deeper aquifers and the drawdowns observed tend to be localized.
7. Pumping of the shallow aquifers can reduce waterlogging and salinisation by lowering pressure levels in the shallow aquifer.
8. Shallow pumping may make additional water available in times of reduced allocations.
9. At present licensing provisions in New South Wales for groundwater allow unrestricted pumping from shallow aquifers.

For the above-mentioned reasons it is useful to identify the potential requirement for shallow groundwater pumping and the potential constraints. The Coleambally Irrigation Area is used as a case study.

METHODS AND RESULTS

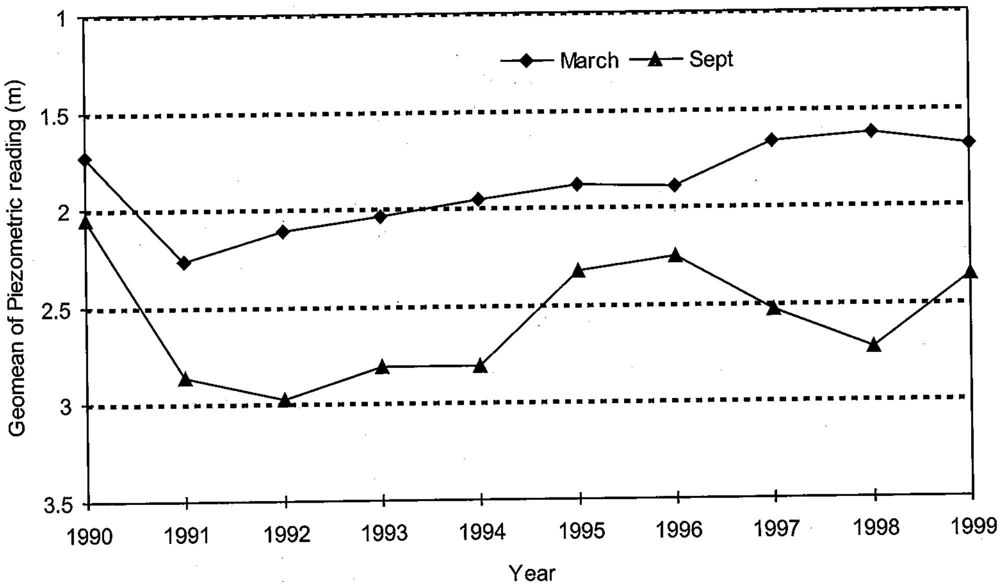
Coleambally Irrigation Co-operative Ltd (CICL) maintains and monitors a network of 605 piezometers inside the boundary of the CIA. These piezometers are read twice a year during February/March and August/September. Piezometric data for the period 1985 - 1999 were available. In 1998 CICL also undertook a salinity survey of these piezometers. The data were analysed to assess the trends in watertables over time and evaluate the suitability of the groundwater resource for conjunctive reuse.

Pumping Requirements

Groundwater Conditions and Drainage Requirement

Groundwater conditions in the Shepparton formation have been extensively reported (van der Lely et al 1987, van der Lely 1992; CICL 1998, 1999). Watertables in the CIA were 20 m deep before the start of irrigated agriculture in the mid 1960s and rose dramatically until reaching their peak in 1996 (CIC 1998) when the watertable was within 2m of the surface over 31% of the CIA. It is reported that piezometric levels have risen since 1986, but they have fallen from 1996-1998. Figure 2 shows an area-wide hydrograph of the geometric mean of piezometric readings for the period 1990-1999 for both March and September. The March values are always higher than the average September readings and display less variation. This is because irrigation takes place during September to March, which causes recharge and hence piezometric levels increase. The final piezometric level does not vary greatly as there is a biophysical constraint in the amount of groundwater discharge, and as irrigation intensity does not vary greatly from year to year the level of recharge is maintained.

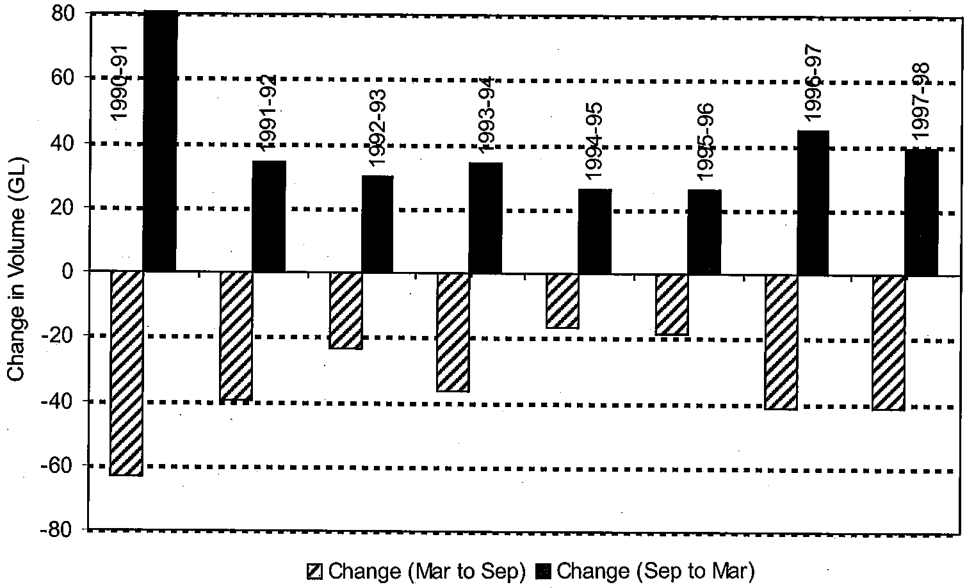
Figure 2: March and September hydrographs of geometric mean of piezometric readings



The September readings display greater variation depending upon rainfall during the non-irrigation period. These trends indicate that shallow groundwater pumping is feasible towards the end of the irrigation season for reuse or during Autumn/Winter if the water is not reused.

Conceptually the use of shallow groundwater pumping is to remove excessive water from the shallow aquifer, thus lowering watertables and hence controlling salinity in the root zone. The lowering of watertables reduces discharge from the watertable by capillary up flow and evaporation, which causes salts to accumulate in the upper layers, and provides the opportunity for salts to be flushed down out of the root zone to the watertable. Thus, there are two aims: preventing discharge and thus salt accumulation, and providing adequate flushing after periods of salt accumulation in the root zone. In September watertable levels are deep (Figure 2) and thus as irrigation occurs there is opportunity for salts to be flushed from the rootzone. As the irrigation season progresses watertables rise and the opportunity for salt leaching is reduced. At the end of the irrigation season watertables are at their highest and the application of water at the surface is stopped. This is the period of greatest risk for root zone salinisation as watertables are shallow and there is no downward movement of irrigation water to balance the upward movement. Thus for shallow groundwater pumping, the most effective period for pumping will be at the end of the irrigation season. The aim is to prevent groundwater discharge by evaporation that leaves salt in the root zone and provides the opportunity for leaching by winter rainfall. By analyzing the watertable surface at different times the change in storage in the upper aquifer can be estimated. Figure 3 shows the area wide net recharge (positive values) and discharge (negative values) for the irrigation season (September to March) and non-irrigation season (March to September). This shows that net discharge occurs in the winter period, varying from 20 to 60 GL per year. If this were evenly distributed over the CIA this would be the equivalent of 0.25 – 0.5 ML/ha/year.

Figure 3: Net change in US aquifer storage for winter and the following summer (Christen et al. 2000)



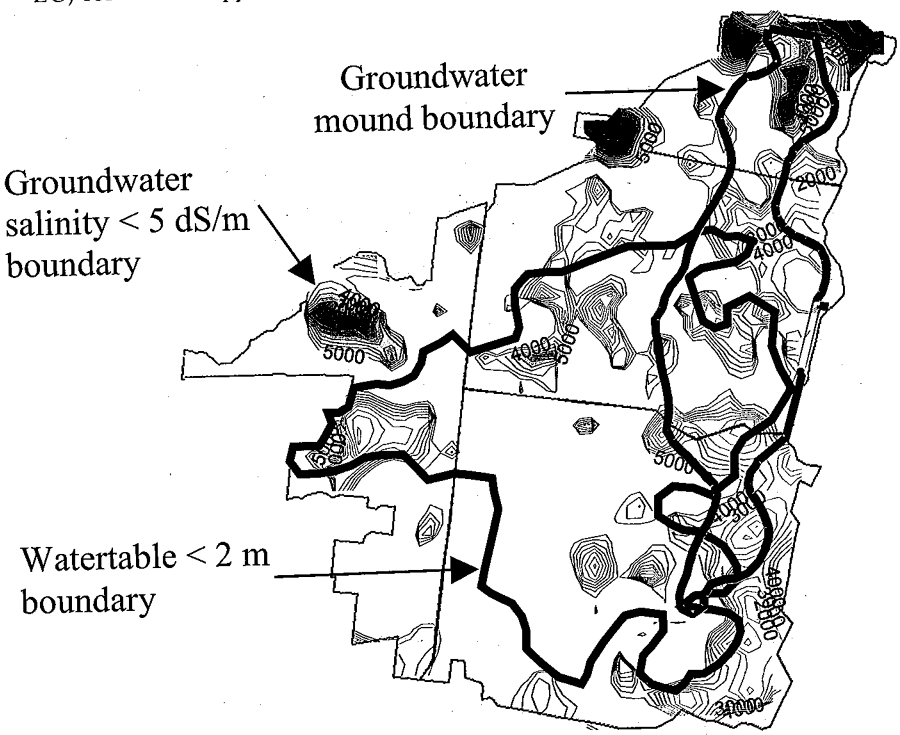
Some of this discharge may occur as downward leakage to the deeper aquifers; however, the majority will be lost to evaporation from the watertable or as discharge into drains and swamps. As well as controlling soil salinity it would be useful to prevent this discharge into surface features by groundwater pumping. Pumping in the autumn period would be useful; however, reuse of the groundwater for irrigation at this time will be less feasible. Groundwater pumping during the peak irrigation season would allow maximum dilution and hence conjunctive reuse, yet this is not the most efficient period for pumping for salinity control. This leads to the need for storage of groundwater and/or off site disposal. The timing of shallow groundwater pumping with respect to efficiency of salinity control and reuse/disposal options is an area that requires further investigation.

SPATIAL ANALYSIS OF REQUIREMENTS FOR SHALLOW GROUNDWATER PUMPING

The criteria for suitability for shallow pumping adopted were that there should be a high water table ≤ 2 m and that the salinity of the groundwater should be ≤ 5 dS/m. These criteria were determined on the basis of potential shallow groundwater pumping of 1ML/ha/year, surface irrigation supply water salinity of 0.2 dS/m, target salinity for conjunctive use of 0.8 dS/m and total irrigation application of 8 ML/ha/year. However, if 0.5 dS/m is taken as the combined salinity then only groundwater up to 3.5 dS/m may be used.

Figure 4 shows the top of the groundwater mound (>122m AHD), the areas where watertable depths were within 2 m of the land surface in September 1999 and where shallow groundwater salinity is less than 5 dS/m. The peak of the groundwater mound is important as this is a high recharge area and is likely to spread an impact on adjoining areas. Where the peak of the groundwater mound and the shallow watertables (<2m deep) overlap will be key target areas for shallow groundwater pumping. The groundwater salinity indicates potential for reuse and need for disposal, generally the eastern margin of the CIA has relatively good quality shallow groundwater, with some more restricted areas of good quality water in the middle and western areas.

Figure 4: Shallow watertables, groundwater mound and areas of salinity less than 5 dS/m (5000 EC) for 1999 in upper Shepparton

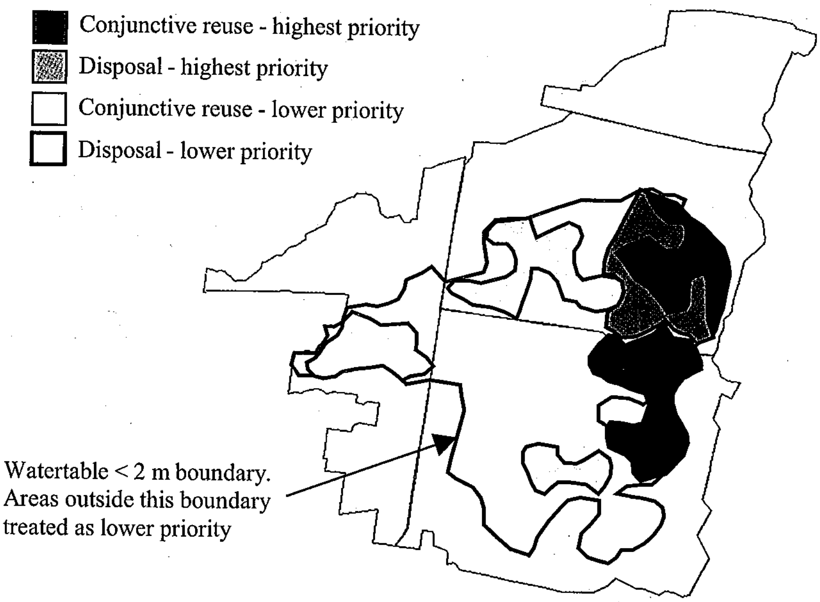


Using this information four areas can be distinguished for shallow groundwater pumping, Figure 5, providing an area-wide first estimate. Obviously site-specific investigations will be required to determine the actual shallow aquifer quality and site suitability for shallow groundwater pumping.

PUMPING CONSTRAINTS

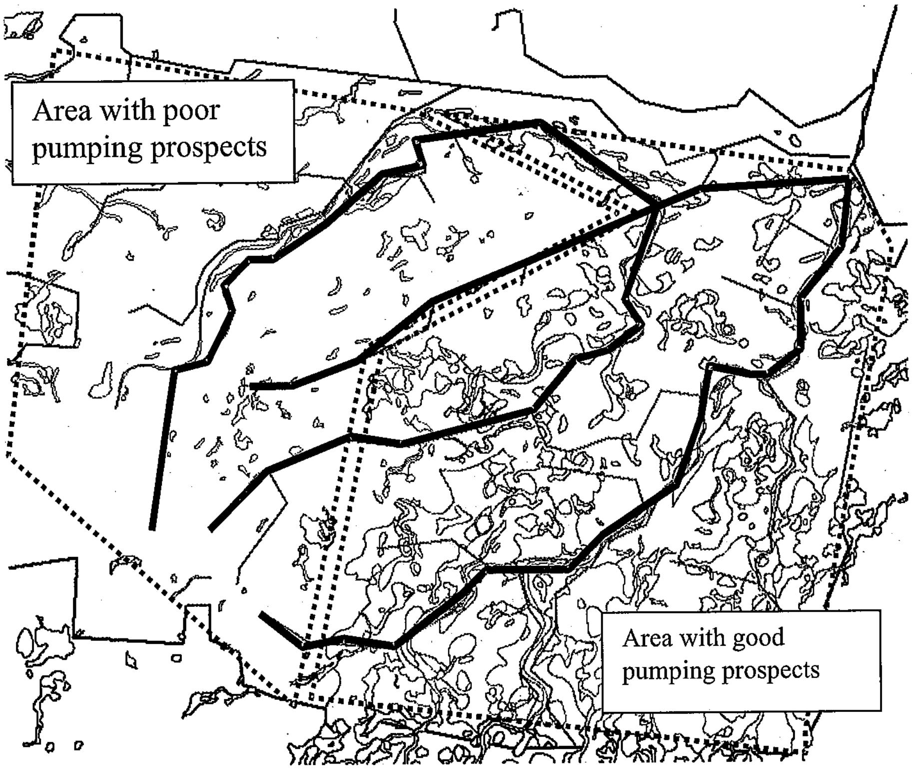
For implementation not only is a detailed understanding of the site specific aquifer geology required but also an assessment of the potential impacts of reuse of more saline water on the local area and downstream water users is needed. This becomes extremely important if saline groundwater is disposed of by dilution into irrigation channels or directly or indirectly (by farm run off) into drainage channels. In this situation the increased irrigation or drainage water salinity will affect the downstream users, thus threatening their productivity and sustainability. This is especially so if the downstream users are restricted in their access to groundwater pumping to control salinity. Restriction to shallow groundwater pumping is due to the absence of suitable aquifers. Figure 6 shows the southeastern section of the CIA with the areas where potential aquifers exist in the background. This is overlain by the channel supply network, over which there are two shaded areas, one being where aquifers for groundwater pumping are generally likely to be present and the other where aquifers are generally less likely to be present.

Figure 5: Potential areas and classes for shallow groundwater pumping



The area where there are poor prospects for finding suitable aquifers is generally at the tail end of the irrigation supply channels. This means that if saline water is disposed of into the supply channel it will be delivered to downstream users who have little opportunity of implementing groundwater pumping themselves. This being the case, careful consideration is required of the equity issues associated with disposal of drainage water by dilution in irrigation channels. Even where the drainage water is reused on farm there is potential for the water to move off farm as surface runoff and thus increase the salinity of the drainage system. This will adversely affect downstream users of the drainage water, who are being encouraged by irrigation companies to reduce the drainage from irrigated areas, especially where there are contaminants in the drainage water.

Figure 6: Potential upstream pumping areas and respective downstream receiving areas (Rogers and Christen 2001)



These complex factors mean that analysis of the potential for all areas to undertake groundwater pumping or some other form of drainage is required before initiating pumping or drainage anywhere. This means that a systematic planned approach to groundwater pumping is required which recognizes that the interests of downstream irrigators have to be protected.

CONCLUSIONS

The area-wide drainage requirement for the CIA was found to be 0.25-0.5 ML/ha/year. The timing of this drainage would be best suited to autumn, thus reducing evaporative loss and discharge to surface features and allowing increased leaching by winter rainfall.

By analysis of the groundwater mound, depth to watertable and shallow aquifer salinity the first estimate of where shallow groundwater pumping needs to be targeted can be made and the opportunity for reuse or the need for disposal can be identified. It was found that there is a groundwater mound along the eastern edge of the CIA, which needs to be reduced as a priority to assist in controlling shallow watertables in the area. Shallow groundwater pumping for conjunctive use can only occur in a small portion of the CIA, as the areas of low salinity water are restricted. Most of the water from shallow pumping will have to be disposed of.

Analysis of the spatial distribution of possible shallow aquifers, and hence, probable pumping sites have shown a very uneven distribution. This requires that area-wide planning to be undertaken before the commencement of pumping to ensure that those in areas with restricted opportunities for drainage are not adversely affected. In the case study area most of the potential pumping area was at the upper end of the irrigation channel network, the tail end areas would have very restricted opportunity for groundwater pumping. Thus serious consideration is required before allowing any increases in irrigation or drainage channel water salinity from upstream pumping and disposal (or runoff) as this may have severe impacts on the downstream users.

ACKNOWLEDGEMENTS

We acknowledge funding from Coleambally Irrigation Co-operative Ltd. and the Australian Centre for International Agricultural Research. Thanks also to all those at Coleambally Irrigation Co-operative Ltd. and the Department of Land and Water Conservation, Leeton for providing the data.

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