SUSTAINABLE PUMPING BELOW A SALINE CLAY IN A MULTI-AQUIFER SYSTEM LOWER MURRUMBIDGEE, AUSTRALIA.

UNSW Groundwater CENTRE

I.Acworth, W.Timms, J.Bell, J.Jankowski

UNSW Groundwater Centre, The University of New South Wales, Sydney.

S.Lawson, P.Kumar

NSW Department of Land and Water Conservation, Leeton.

LAND & WATER CONSERVATION

INTRODUCTION

Sustainable agriculture is protecting our land and water resources whilst developing the profitability of industry. Over $1 billion of produce for domestic consumption and export markets is provided by the Murrumbidgee catchment.

Water management must incorporate both quality and quantity aspects of a combined resource: surface water and groundwater. Groundwater flows slowly through the earth, but is closely linked with rivers and lakes.

RECENT HISTORY

Development of Coleambally Irrigation Area (Fig. 1) commenced in 1960 and was completed by 1973. Most irrigation water is obtained from the Murrumbidgee River, whose flow is augmented with supplies diverted inland by the Snowy Mountain Hydroelectric Scheme.

Regional water table levels that were at least 20m below the ground surface prior to commencement of irrigation are, in many areas, now very near the ground surface. Irrigation without sufficient drainage may lead to rising water table levels. Rising water tables are associated with water logging problems and salinity in the soil zone, and can also be associated with potential leakage of saline groundwater to deeper fresh aquifers.

The role of groundwater pumping in supplementing irrigation water supplies and controlling watertable rise has been limited by low permeability and concerns over induced leakage of poor quality water.

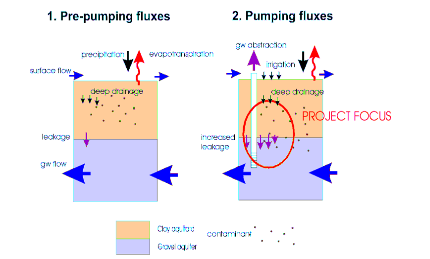

Figure 2. Conceptual model of contaminant mobilisation.

PROJECT HYPOTHESES

- Large scale pumping of ground water from fresh water, high yielding aquifers is significantly increasing downward hydraulic gradients.
- Salts stored in saline clay aquitards are mobilised, and may potential contaminate underlying fresh aquifers (Fig. 2).

RESEARCH OBJECTIVES

This collaborative project is helping to improve our understanding of complex multi-level groundwater systems containing saline clays. Groundwater response to increased recharge and vertical leakage due to pumping and irrigation activities may then be assessed with greater confidence.

- How much leakage through clay is due to pumping from deep aquifers ?
- How fast does groundwater move through clay ?
- Do salts and other contaminants also move ?
- How much groundwater can safely be pumped ?

Figure 3a. Drilled holes are completed with piezometers at several depths.
Figure 3b. Drilling techniques allow recovery of minimally disturbed cores.

Figure 4a. Geophysical techniques are used to detect clay and salt.
Figure 4b. Unstable chemical parameters are measured in the field.

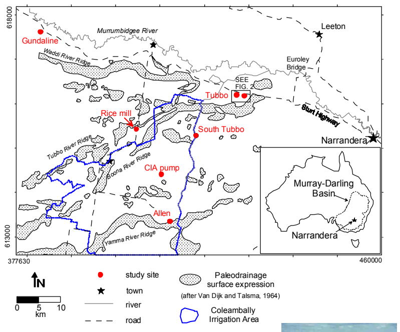

Figure 1a. Location of study sites.

Figure 1b Main Channel, Coleambally Irrigation Area   Figure 1c CIA pump bore

METHODS

Drilling, coring and piezometer installation - specially developed drilling techniques are used to obtain minimally disturbed core. Holes are completed with nested (Figure 3) monitoring bores with intake screens at several depths.

Geophysical investigation – helps to determine subsurface distribution of clay and salt by electrical imaging and downhole bulk EC and natural gamma logging (Figure 4).

Groundwater dynamics – piezometers are equipped with automated groundwater level loggers to monitor response to rainfall and pumping.

Groundwater chemistry – variation of groundwater quality with depth, and over time. Sampling includes unstable field parameters (eg. pH, DO), major elements (eg. Na, Cl), minor and trace elements (eg. Fe, Sr) and nutrients (eg. NO_3, PO_4). Naturally occurring isotopes (eg. ^{18}O, ^{2}H, ^{3}H, ^{14}C) are signatures of mixing and residence time.

Laboratory analysis of clay cores - measurement of particle size, mineralogy, density, porosity, and pore water chemistry from which salt storage profiles are calculated.

Geotechnical analysis - clay core is also tested for permeability and consolidation. This enables the rate of pore pressure dissipation and potential settlement due to dewatering to be determined.

Flow modeling– a state-of-the-art FEFLOW system is used to study groundwater flow pathways constrained by hydrodynamic and hydrochemical data collected.

Hydrochemical modelling: quantitative modelling of plausible mixing scenarios including interaction with clay materials via ion-exchange and dissolution.

SALT STORAGE IN CLAY

Significant quantities (tonnes/ha) of salt are stored in the upper aquitard (Fig. 6), although deep aquitards are non-saline. The aquitards are comprised of clayey silt through which water (and dissolved salts) leaks very slowly.

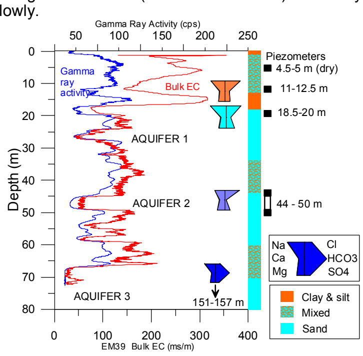

Figure 6. Bulk EC and gamma logging suggests there may be significant stores of high concentration salts in upper clay aquitard.

SPATIAL DISTRIBUTION OF SALINE CLAYS

Electrical images reflect the heterogeneity of the subsurface to about 20 m depth due to changes such as lithology and salt content. In some areas, paleochannels are buried beneath only a few metres of clay. The discontinuous nature of the clayey deposits means that shallow groundwater is vulnerable to contamination by agricultural activities (Fig. 5).

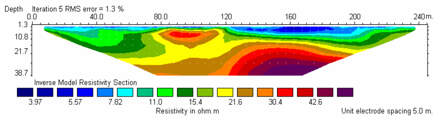

Figure 5. Interpreted electrical imaging showing possible paleodrainage channel.

CHANGING GROUNDWATER QUALITY

Groundwater salinity in the shallow aquifer has increased at some sites over the medium term (Fig. 7). No major changes have been observed in the deeper aquifers, due to dilution effects and the presence of deep non-saline aquitards acting as hydraulic barriers to leakage.

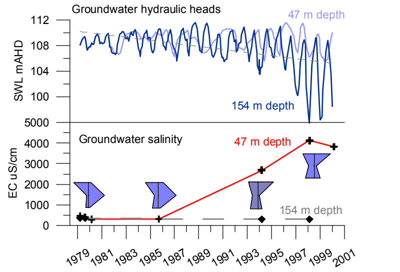

Figure 7. Fluid EC (uS/cm) at the Rice Mill site has been observed to increase significantly between 1985 and present. Note long term decline in water levels.

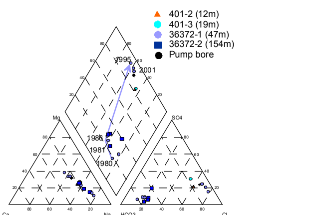

Figure 8. Piper diagram illustrating evolution of hydrochemical composition over the medium term at Rice Mill site.

Hydrochemical changes (Fig. 8) may be accounted for by mass balance modelling which indicates dissolution of salts from clay, and mixing of up to 30% of saline clay pore water with aquifer water.

Groundwater quality also changes over the short term, due to leakage and mixing during the irrigation season.

e.g. Na-HCO_3 ⇒ Na-Mg-Ca-HCO_3-Cl water type

Nutrient levels were found to be low and are not currently a concern, though shallow groundwaters are vulnerable.

FURTHER INVESTIGATIONS AND CONCLUSIONS

Significant leakage of shallow saline groundwater may occur through aquitard "windows" and leaky bore holes that are corroded or gravel packed. This process is being quantified with FEFLOW. Further research is also focused on rapid groundwater level change within clay aquitards. These observations are related to the response of clay to overburden pressure changes, in addition to physical flux of groundwater.

Clearly, shallow saline groundwater is a concern not just near the surface but also at depth. Balancing the quantity of pumping with groundwater quality protection, is a challenge for sustainable agriculture.

FUNDED BY:

NSW Land & Water Conservation, Land & Water Australia, Coleambally Irrigation Ltd, Natural Heritage Trust, and UNSW School of Civil & Environmental Engineering - Water Research Laboratory.

FURTHER INFORMATION: www.wrl.unsw.edu.au   MAY 2001