Progress with recharge studies in the lower Namoi valley

J. Triantafilis[1,2], J. Cuppitt[1,2] and A.B. McBratney[2]

[1]Cooperative Research Centre for Sustainable Cotton Production,
Australian Cotton Research Institute, Narrabri, NSW 2390
[2]Cooperative Research Centre for Sustainable Cotton Production,
Dept. of Ag. Chemistry and Soil Science, The University of Sydney, NSW 2006

Introduction

Groundwater is water that has drained through the soil and accumulated at depth within the deeper subsoil or in bedrock. Groundwater recharge is the process whereby the surplus of infiltration over evapotranspiration drains from the root-zone and continues to flow downward through the so-called vadose-zone toward the ground-water table (Gee and Hillel, 1988). The vadose zone is the volume of deeper subsoil, that is not as biologically active as the root-zone, where deep drainage or recharge occurs. The vadose zone is as heterogenous in nature as the topsoil it lies beneath and because of its inaccessibility is more difficult to map and hence understand the processes occurring in this part of the subsoil. In areas where irrigation is carried out extensively and over a prolonged period of time, such as the irrigated cotton growing areas of northern New South Wales, information is necessary in order to determine the amount of excessive infiltration through the topsoil and the quantity and fate of the deep draining waters through the vadose zone.

Recently much work has been carried out in the use of airborne geophysics in generating information for the delineation of large stores of soluble salts or the identification of recharge/discharge areas, etc. Despite its advantages in efficiency of data generation over reasonably large areas the cost of such technology is high (up to $5/ha.), however. An alternative to this approach is the use of ground based Electromagnetic (EM) techniques using instruments like the Geonics Ltd EM34-3. This instrument, along with some soil sampling, has been used successfully to measure and map the extent and causes of dryland salinity (Dixon, 1989), locate sub-surface saline material (Williams and Baker, 1982), for groundwater exploration (Potts, 1990), describing the spatial distribution of soil salinity and clay content (Williams and Hoey, 1987) and inferring recharge and discharge areas (Williams and Arunin, 1990). More recently, and coupled to groundwater recharge models it has been used successfully in estimating recharge (Cook *et al.*, 1989a) and describing the spatial distribution of recharge (Cook *et al.*, 1989b).

In the following paper we show how the EM34-3 is being used to provide quantitative estimates of soil electrical conductivity (ie. EC_a) and how the spatial distribution of this data can be related to the physiography (geology and geomorphology) and hydrogeology of the lower Namoi valley. We also suggest how this information can be used in groundwater recharge studies.

Materials and Methods

The study area selected is approximately centred around the small township of Wee Waa which is located in the lower Namoi valley in northern New South Wales. The survey area covers 2,048 square kilometres and is roughly bounded by Bald Hill Road in the east and

Cubbarroo Lane in the west, and extends as far north as Boolcarrol Farm and includes the cotton growing areas of Myall Vale, Doreen Lane and "The Gardens" as illustrated in Figure 1. The area was chosen since it is one of the oldest irrigated cotton growing areas and because a large number of farms are concentrated in a relatively small area. They are however, interspersed with pastoral and dryland cropping areas which could provide comparisons with the irrigated cotton growing farms.

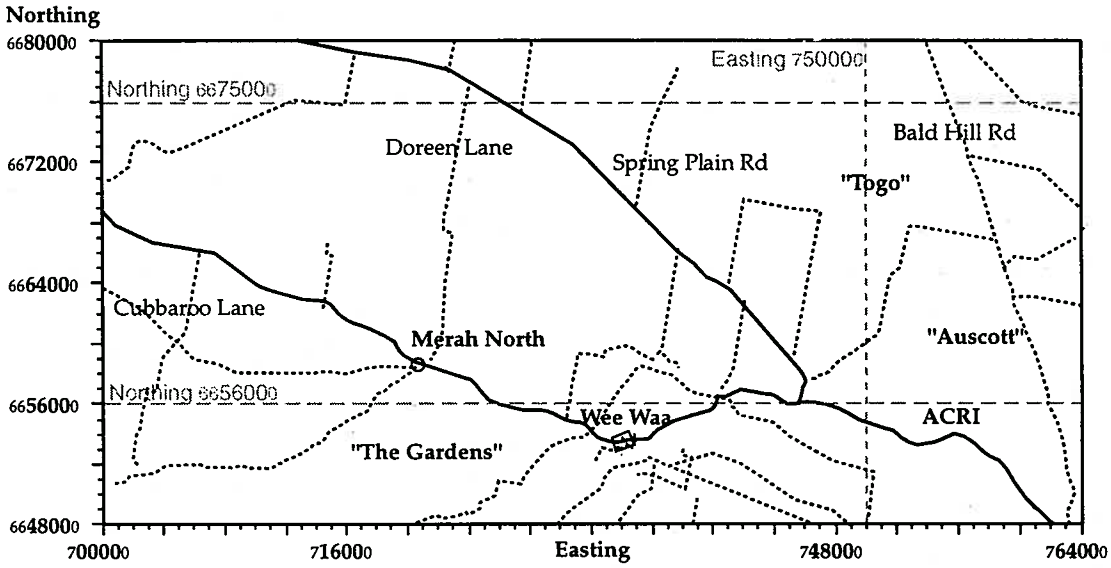

Figure 1. EM34-3 survey area of the lower Namoi valley.

Stannard and Kelly (1977) carried out a reconnaissance soil survey of this part of the lower Namoi valley and identified eight physiographic units including the clay plains, prior stream formations and the low dissected floodplains. These three units now form the principal irrigation districts of the area although some irrigation is also carried out in and around the Pilliga Scrub complex. Figure 2 shows the location of these physiographic units. It is apparent that the clay plains dominate the area and are generally uniform in topography except where dissected by present streams. The uppermost sediments are of a fine textured nature upon which clay soil of a self-mulching character have developed.

The prior stream formations mostly occur in continuous belts of slightly elevated and undulating land, the uppermost materials of this formation are of a coarser texture than the clay plains. The relic stream channels and levees are distinguishable, with the former underlain by coarse channel sediments. In some areas, the stream channels are located in lower lying areas with respect to the plain, acting as preferential paths for floodwaters under current conditions. In these situations, the upper sediments are of a fine texture and are identifiable from the normal effluents by their wide meander belts and broad and shallow channels, (Stannard and Kelly, 1977).

The coarse dissected low floodplains lie adjacent to the Namoi River between Narrabri and Wee Waa usually occupying depressed positions with respect to the clay plain and are often dissected by small flood channels. The greatest contribution of this generally coarse textured low flood plain material is the result of dissection of Pilliga Scrub by the course of a prior stream formation. Elsewhere, the low dissected lands associated with the river and effluents are uniformly textured (Stannard and Kelly, 1977).

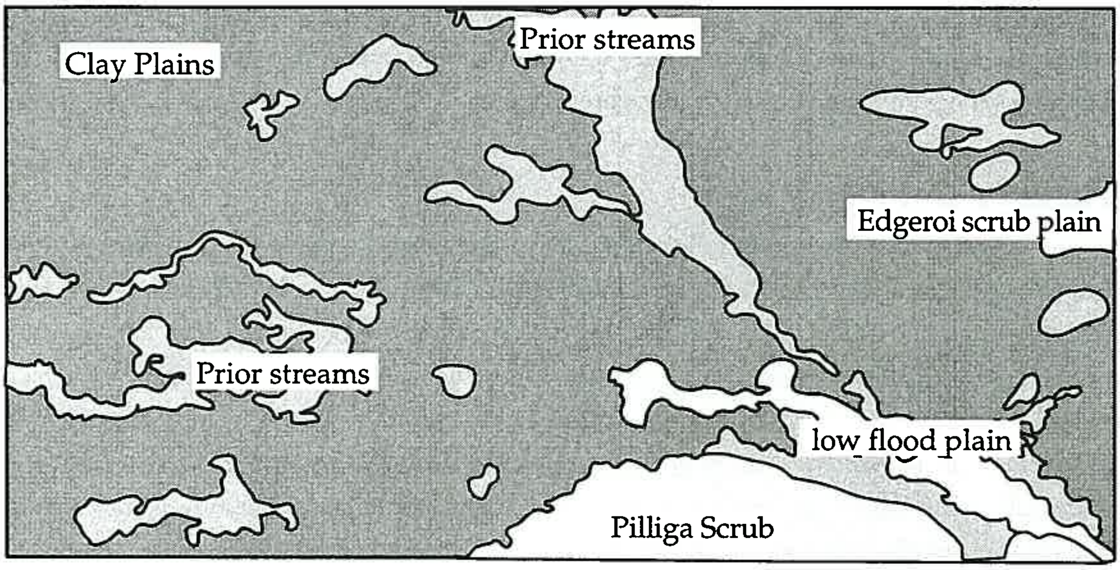

Figure 2. Physiography of the lower Namoi valley (after Stannard and Kelly, 1977).

In order to map this area and confirm these patterns, whilst at the same time providing quantitative EC_a information an EM34-3 survey design was developed and involved taking measurements with the instrument on an approximate 1 km grid. Unlike the EM38 and EM31, the EM34-3 consists of two independent coils that are connected via a flexible cord, (see Figure 3a). As the name implies the instrument can be used at three fixed coil configurations. The intercoil spacing can be varied by the user(s) and is measured electronically so that the receiver operator determines the effective depth of penetration by fixing the coils to either 10, 20 or 40 m. At these intercoil spacings the instrument senses to depths of 7, 15 and 30 m, respectively in the horizontal modes of operation.

Figure 3a. A Geonics EM34-3 instrument.

Figure 3b. Subsoil sampling to estimate deep drainage.

Where measurements of soil EC_a were generated using the EM34-3, a small and relatively inexpensive Magellan NavPro5000 GPS was used to provide positional information. Additional accuracy was generated using a RDS1000 FM Receiver which provides differential corrections for sub-meter accuracy. In total an area of 204,800 hectares was covered and included visits to over 120 irrigated cotton, dryland cropping and grazing properties as well as along stock routes and native forest areas. The location of the 1869 EM34-3 survey points is illustrated in Figure 4.

Results and discussion

Figure 4 also shows the relative EC_a measurements achieved using the EM34-3 in the horizontal mode of operation and at an intercoil spacing of 40 m. The data presented here strongly reflects the geological and geomorphological perceptions of the area and suggests possible soil types where deep drainage may be of concern. This is particularly the case where the instrument and the survey reflected the location and passage of prior stream channels of the Namoi River in a north west direction parallel with Spring Plains road and in a westerly direction where Pian Creek now runs. These areas are defined by lighter shaded areas where soil EC_a was generally low. This is similar to the physiography map of Stannard and Kelly (1977). It is in these prior stream areas where the soil is sandier in nature and where potential problems with excessive ground-water recharge needs to be investigated.

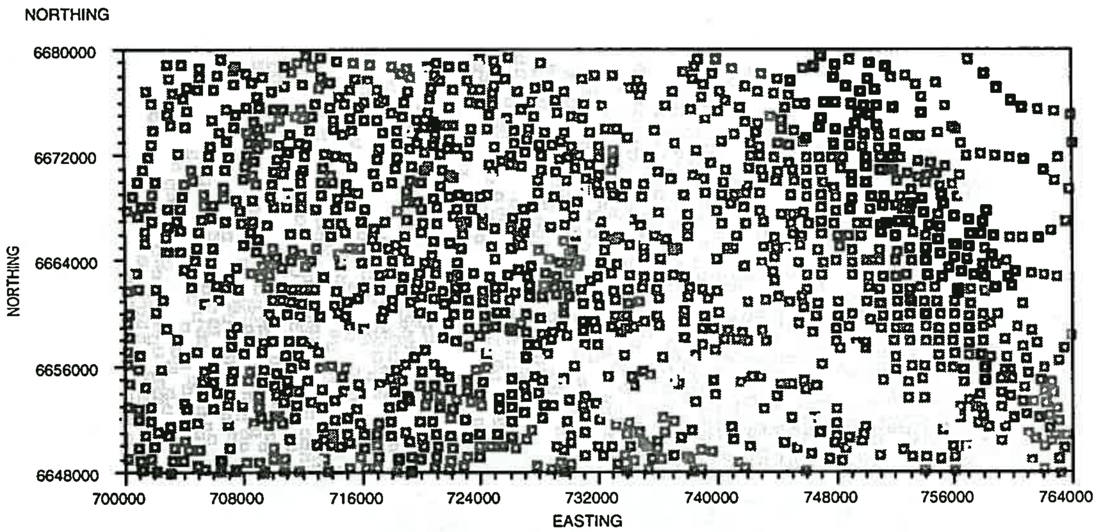

Figure 4. Map of low, intermediate and high soil ECa (mS/m) as obtained using EM34-3 in horizontal mode of operation and an intercoil spacing of 40 m.

This is more clearly illustrated when considering data along single east-west or north-south transects as illustrated in Figures 5 and 7, respectively. Figure 5 illustrates two transects generated almost 20 km apart along east-west traverses across the study area. The upper panel shows the EC_a measurements at 10 and 40 m intercoil spacings along Northing-6675000, while the lower panel shows similar data generated along the more southern transect of Northing-6656000. The location of these transects across the study area are indicated in Figure 1.

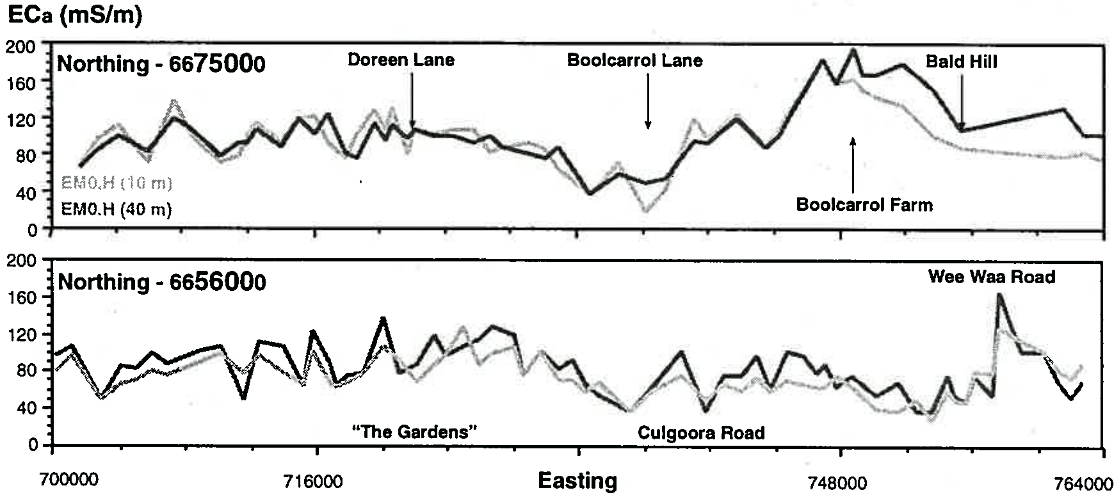

Figure 5. East-west transects of $EM_{0,H}$ at 10 and 40 m intercoil spacing.

It is obvious from these two transects that survey points located adjacent to or within prior stream channels, (ie. near Boolcarrol Lane in the upper panel and Culgoora Road in the lower panel), soil EC_a is generally much lower than on the clay plains in areas such as Doreen Lane and "The Gardens". The reason for this is that the soil is generally coarser in texture (ie. sandier) than the clay rich plains. As a consequence the soil is much less conductive. This is better appreciated by considering a cross-sectional view of the general shallow stratigraphy near prior stream channels as identified by Stannard and Kelly (1977) and illustrated in Figure 6.

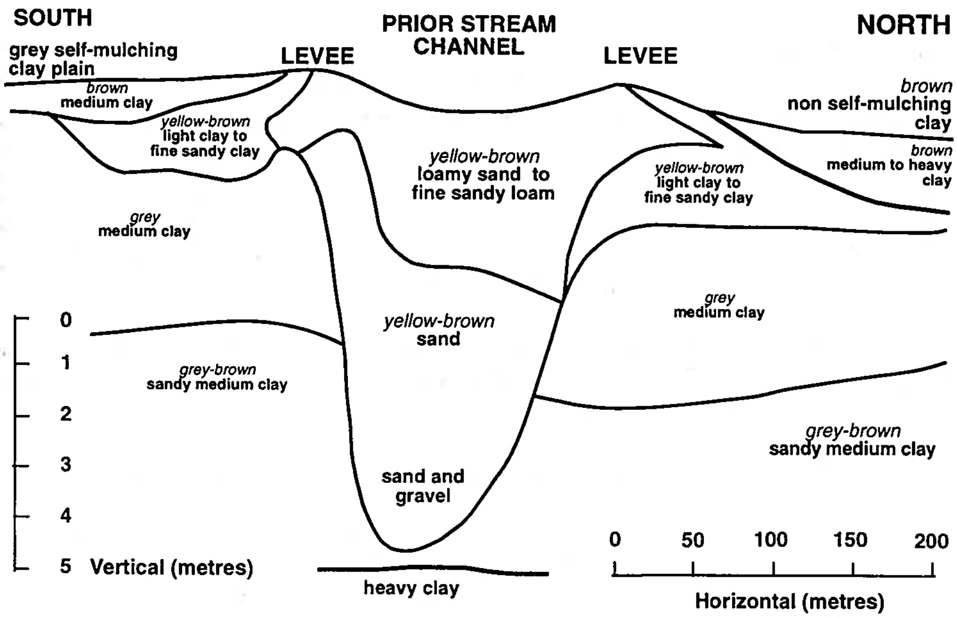

Figure 6. Cross section of a prior stream channel in lower Namoi valley, (after Stannard and Kelly, 1977).

The thickness of the clay alluvium near prior stream channels is also quite variable. This is reflected in the transects shown in Figure 5, even though the 1 km grid adopted here is coarser than the variation of alluvium. Despite this, there is still an increasing trend of soil EC_a away from these channels, which suggests that the thickness of the clay alluvium increases. The depth of this clay can be as much as 10 m, particularly in the areas to the north of Myall Vale (Triantafilis, 1996). However underlying this material the soil is generally sandier consisting of clayey sand and sandy medium clay layers that are not as conductive as the clayier material above (see Figure 6). This is reflected by both horizontal modes of operation shown (ie. $EM_{0,H\,(10m)}$ and $EM_{0,H\,(40m)}$) and suggests that the instrument in each mode of operation is responding to similar geological features of the landscape (ie. clay content and thickness of clay alluvium, particularly on the plains).

This is not entirely the case in the prior stream channels and in an area of the plain located to the north of Myall Vale and the Australian Cotton Research Institute (ACRI). In the prior stream channels it is apparent that soil EC_a as measured using the EM34 at a 40 m intercoil spacing is slightly larger by comparison to soil EC_a as measured by the 10 m intercoil spacing. The reason for this would appear to be that the instrument with the coils aligned at a 40 m interval is able to respond to the presence of a deep subsoil clay layer or some other conductive material, such as groundwater. This is best illustrated by considering the data presented in Figure 7 which shows in the upper panel the soil EC_a as measured at intercoil spacings of 10 and 40 m, from south of the ACRI near the Namoi River and its floodplain to Boolcarrol Farm some 30 km to the north. The lower panel shows the ratio of soil EC_a as measured using the EM34-3 at a 40 m and 10 m intercoil spacing.

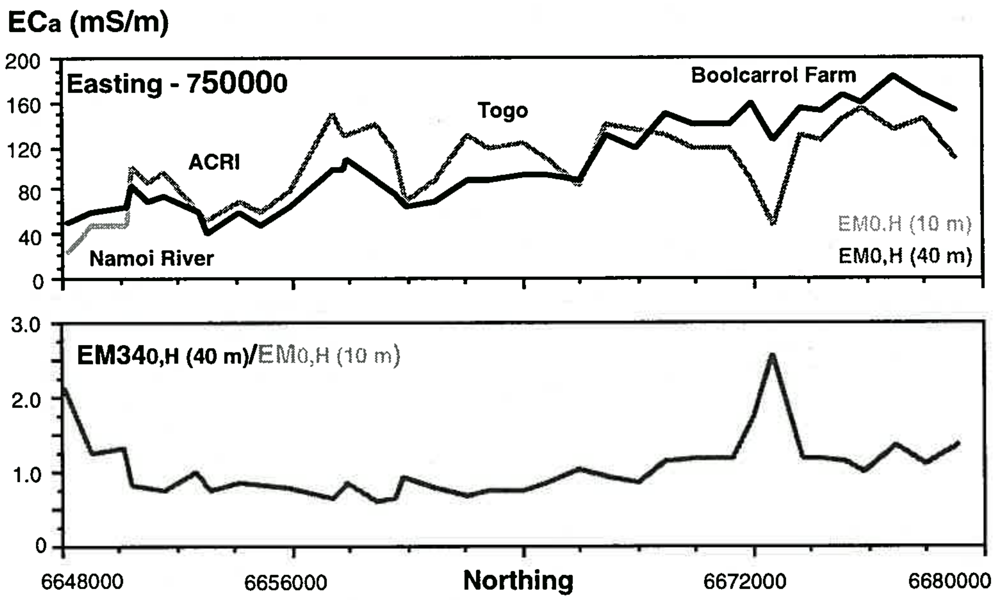

Figure 7. North-south transect of $EM_{0,H}$ at 10 and 40 m intercoil spacing.

What is apparent in the upper panel is the steadily increasing trend in EC_a from the southern part of the area to the north. This is consistent with increasing clay content and thickness of clay the further away we travel from the river floodplain. However, more significantly near the Namoi River the ratio of $EM_{0,H\,(40)}$ and $EM_{0,H\,(10)}$ is quite large as indicated in the lower panel of Figure 7. This suggests that the instrument when used at the 40 m intercoil spacing is probably being influenced by groundwater at a depth of about 15-20 m. This is beyond the measurement depth of the instrument when used at an intercoil spacing of 10 m. The reason for the even larger ratio on Boolcarrol Farm is most likely due to the presence of a number of relatively saline aquifers situated at depths of approximately 25 m in this general vicinity. Figure 8 shows the location of these saline aquifers (eg. 1500 < salts < 3000 mg/L) in the east and north eastern part of the study area but also illustrates the very good quality water located beneath the clay plains and prior streams (ie. salts<500 mg/L) which most people use for irrigated cotton production.

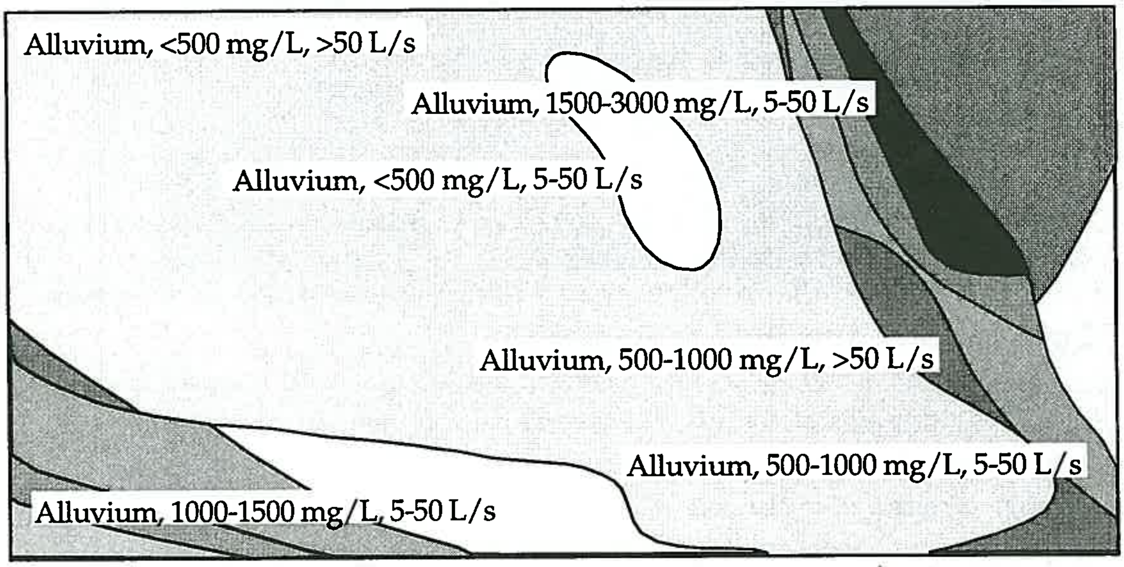

Figure 8. Hydrogeology of the lower Namoi valley area (after Department of Water Resources, 1988).

This is more clearly demonstrated in Figures 9 and 10 which show interpolated maps of the 1869 soil EC_a measurements made with the EM34-3 at 10 and 40 m intercoil spacings, respectively. Figure 9 clearly defines the location of the prior stream channels and clay plains and shows the relationship between the roads of the area and the sandier soil types associated with the prior stream channels. The prior stream channels are better defined using the 10 m separation since the instrument in this operation mode is better able to respond to the variability in soil EC_a to a depth of 7.5 m.

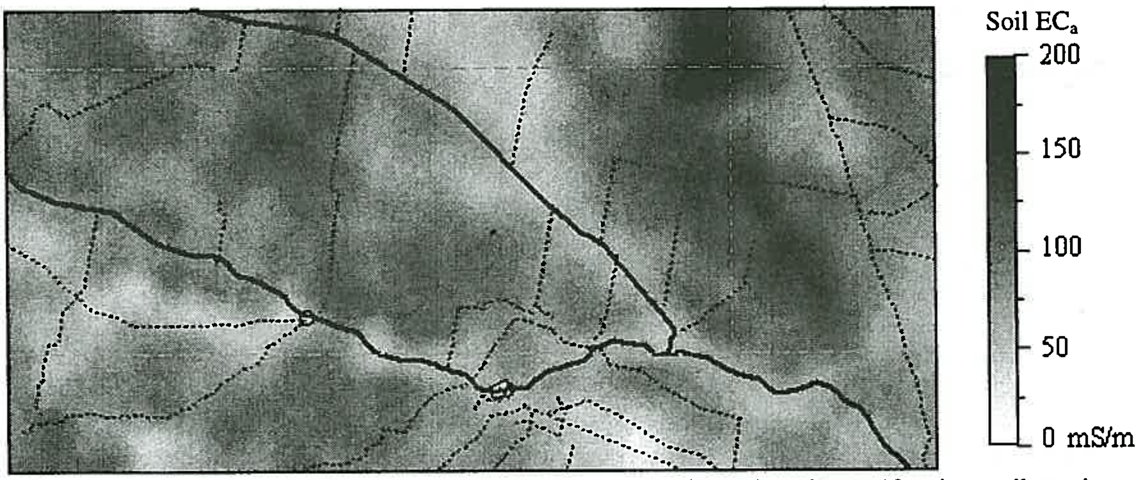

Figure 9. Map of soil EC_a as obtained using the EM34-3 in horizontal mode at a 10 m intercoil spacing.

On the other hand and despite the fact that the EC_a data generated at the 40 m intercoil spacing also reflects the location of the prior stream channels, Figure 10 clearly highlights the location of the slightly saline aquifers bounded in the east by Bald Hill Road, to the south by Wee Waa Road and south-west by Spring Plains Road.

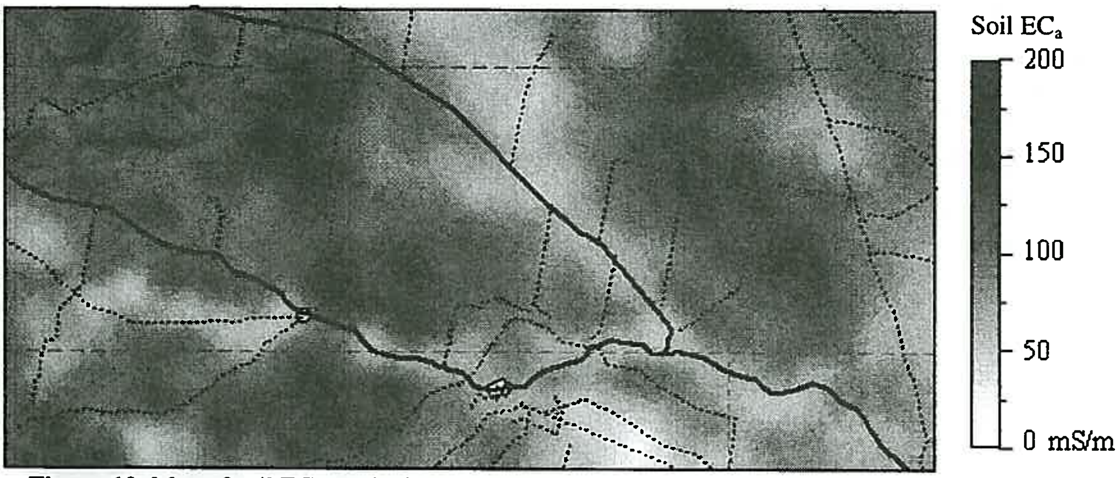

Figure 10. Map of soil EC_a as obtained using the EM34-3 in horizontal mode at a 40 m spacing.

Conclusions and Future Research

The work carried out to date suggests the EM34-3 instrument is capable of describing the spatial distribution of soil EC_a, the general physiography and geomorphology, and the geohydrology of the lower Namoi valley study area. Future work will involve coupling estimates of recharge to the soil EC_a information collected using models and from soil samples collected (see Figure 3b) from the various land-use types for comparison

Acknowledgments

This work is funded by the Cotton Research and Development Corporation and Salt Action through a Coordinating committee of the lower Namoi valley water users association community based project NW1056.94 entitled "Understanding the salinity threat in the lower Namoi valley". We thank Mr Jerry Killen (Chairman) and Phil Norrie (Secretary) for supporting the project and assisting in administering the funds. We also acknowledge the cooperation and support of all land-holders who allowed us unrestricted and unconditional access to all areas of their farms.

References

Cook, P.G. & Walker, G.R. (1992). Depth profiles of electrical conductivity from linear combinations of electromagnetic induction measurements. *Soil Science Society of America Journal* **56,** 1015-1022.

Cook, P.G., Hughes, M.W., Walker, G.R. & Allison, G.B. (1989). The calibration of frequency-domain electromagnetic induction meters and their possible use in recharge studies. *Journal of Hydrology* **107,** 251-265.

Department of Water Resources (1988). Narrabri Hydrogeological Map. Department of Water Resources, NSW.

Dixon, P. (1989). Dryland salinity in a subcatchment at Glenthompson. Victoria. *Australian Geographer* **20,** 144-152.

Gee, G.W. and Hillel, D. (1988). Groundwater recharge in arid regions: review of methods. *Hydrological processes* 2, 256-266.

Potts, I.W. (1990). Use of the EM-34 instrument in groundwater exploration in the Shepparton region. *Australian Journal of Soil Research* **28,** 433-442.

Stannard M.E. & Kelly, I.D. (1977). 'The irrigation potential of the lower Namoi valley.' (Water Resources Commission, NSW).

Triantafilis, J. (1996). Quantitative assessment of soil salinity in the lower Namoi valley. PhD Thesis. The University of Sydney.

Williams, B.G. & Arunin, S. (1990). Inferring recharge/discharge areas from multifrequency electromagnetic induction measurements. CSIRO Division of Water Resources, Technical Memorandum 90/11 November.

Williams, B.G. & Baker, G.C. (1982). An electromagnetic induction technique for reconnoissance surveys of soil salinity hazards. *Australian Journal of Soil Research* **20,** 107-118.

Williams, B.G. & Fiddler, F-T. (1983). The use of electromagnetic induction for locating subsurface saline material. In 'Relation of groundwater quantity and quality' (Proceedings of the Hamburg Symposium, August 1983). IAHS Publishing No 146, 189-196.

Williams, B.G. & Hoey, D. (1987). The use of electromagnetic induction to detect the spatial variability of the salt and clay contents of soil. *Australian Journal of Soil Research* **25,** 21-28.