Hovell's Creek LCG Electro-magnetic Induction Survey

Dryland Salinity Investigation

N S W D e p a r t m e n t o f L a n d a n d W a t e r C o n s e r v a t i o n

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Dryland Salinity Investigation

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Salt Action

Acknowledgments

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CONTENTS

Page

LIST OF FIGURES

Page

SCOPE OF THE INVESTIGATION

Dryland salinity is one of the important issues facing landholders in Central West NSW. Each salinity-affected site has different characteristics and there is a need for site specific information to plan and/or apply appropriate treatments.

An Electro-magnetic Induction (EMI) survey coupled with validation is one method to obtain site-specific data, this was carried out for the Hovell's Creek Landcare Group. Funding was attained through the 'Salt Action' program (NSW government funded) and personnel from the DLWC-Cowra carried out the survey.

The aim of the investigation was to map and identify wet and possibly saline areas. When compared to the surrounding landscape of the Hovell's Creek Landcare Group, the EMI survey can be used to define how large and severe a current saline site is, it's potential spread and where possible future saline areas might occur.

The EMI survey was carried out on properties within the Hovell's Creek Landcare Group focusing mainly on saline hazards (Figure 1). Salinity is evident in the Hovell's Creek Landcare Group and the properties surrounding the group.

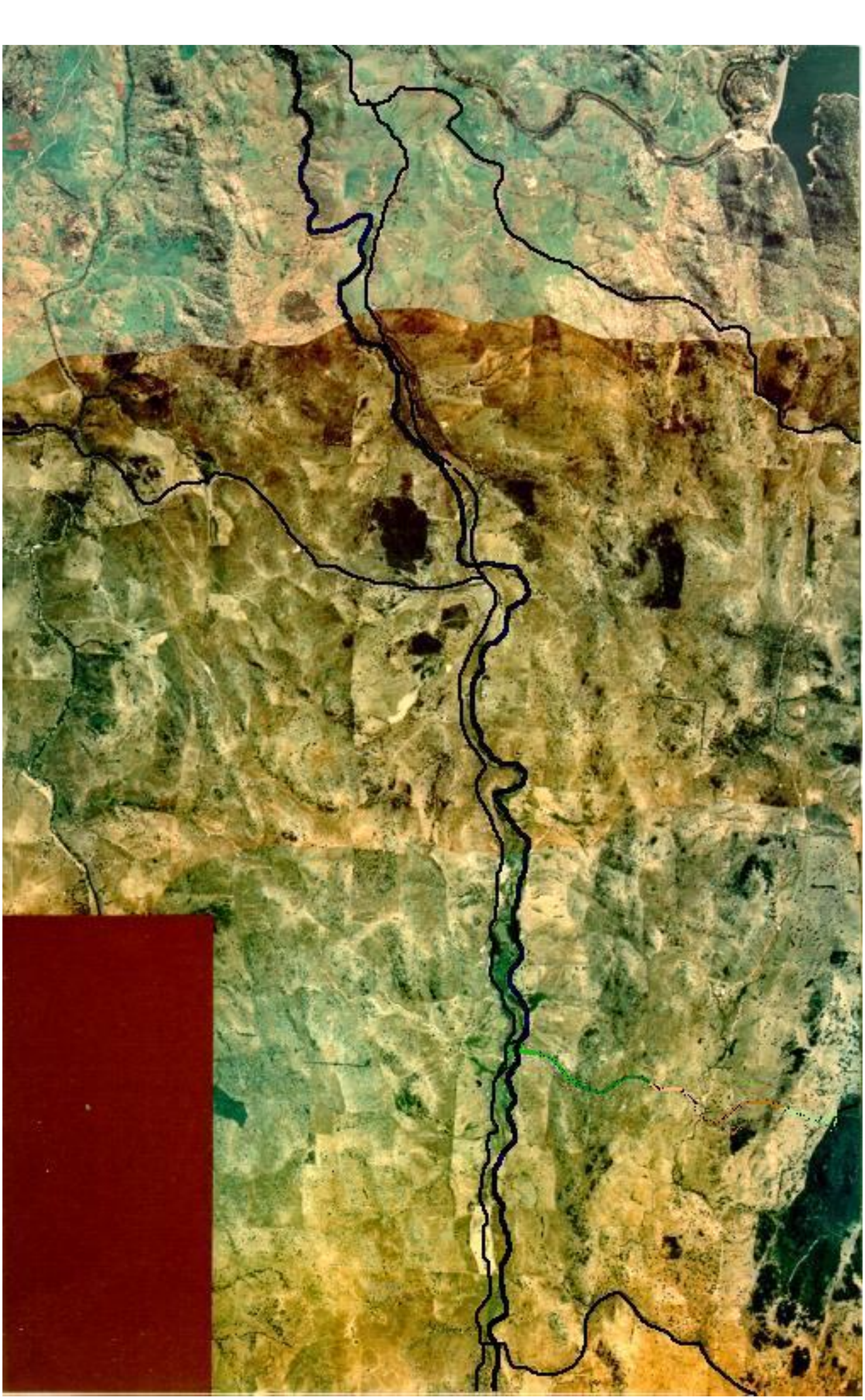

Figure 1. Aerial photo of Survey area and Hovells Landcare Group.

LAND & WATER CONSERVATION

SUMMARY

The aim of the investigation was to map and identify wet and possibly saline areas within properties of the Hovells Creek Landcare Group (Figure 1). An EMI survey and its validation are one method to obtain site-specific data.

The survey helped identified current and possible future saline areas and highlighted the differences between the landscape types in the area, recommendations where tailored according to these differences.

The Hovells Creek LCG was split into three main zones, these consist of:

Zone 1 – Hovells Creek River Flats

Transported sands and clays, prone to flooding and waterlogging. Highly saline areas exist within the zone. These areas need immediate attention (saline agronomy) to include them into current production, with the surrounding area needing tailored landuse changes to increase water use and productivity.

Zone 2 – Slightly Weathered Granite

Rocky outcrops and hill slopes with large exposed boulders. Waterlogging areas occur at the break of hill slopes. These are mainly to the east of the Survey area. These areas need to be managed to utilise water more efficiently to help decrease groundwater recharge.

Zone 3 – Moderately Weathered Granite

Rocky outcrops to the South and West of the survey area, prone to perennial slightly brackish springs that occur right up to the top of sub-catchments. These areas need to be managed similar to Zone 2 areas with more focus on the utilising the springs as a water source.

Validation of all high conductivity (pink) areas was carried out using the property EMI survey maps and historical information obtained from the landholder. Most areas had salinity symptoms, varying from change in pasture species to scalding and waterlogging.

B A C K G R O U N D   I N F O R M A T I O N

The Hovell's Landcare Group conducted a salinity awareness project, which included a small scale EMI survey, instillation of monitoring bores and a hydro-geological study. The report highlighted factors contributing to the areas affected by salinity. Changes in soil texture at the break of slope was causing saline groundwater to come within 1.5 m of the surface, causing salinity symptoms in the flood plain, evaporation and capillary rise being one of the main factors (Muller *et al*, 1998).

Vegetation Background

The clearing of vegetation for agriculture removed deep rooted and diverse vegetation capable of using rainfall and surface water where it fell, with little recharge entering the shallow groundwater system.

The shallow rooted pastures and grazing systems used in farming areas do not use all available moisture and inturn increase groundwater recharge. This increases the total volume of water in the groundwater system making the water table rise in certain places.

Geology and Regolith

Principal geology in the area is Wyangala Granites (foliated porphyritic biotite granite). These rocks are intrusive from deep within the crust and where formed some 410M years ago (Silurian, COWRA 1:100000 - Geology). Within the Hovells Creek flow line some areas of granite geology is overlain with sands and gravels deposited some 50M years ago.

There are other areas of the granite geology that are more fractured and weathered than others, these areas can be defined as moderately weathered or slightly weathered. Areas that are moderately weathered tend to generate more clayey soils and can be more fractured than the slightly weathered geology.

There are large areas of clays that where formed (20,000 years ago) from the weathering of the volcanic sediments which are acting as stores for cyclic salts. These clay deposits can also cause seasonal water logging by forming perched water tables in low-lying areas, through the actions of capillary rise and evaporation salinity symptoms can be caused.

Ground Water Levels

Where salt bearing groundwater rises to within 2 to 4 meters of the surface, the affects of dryland salinity can be seen. These include decreases in pasture health and crop productivity, invasion of salt tolerant plants, tree decline, scalding and erosion.

Groundwater levels are very important in the determination of salinity and why it occurs in certain areas. Water moving through rock and soil collect salt forming minerals and cyclic salts, which over time get transported to discharge zones. Depending on ground water levels at a discharge zone, capillary rise and evaporation may allow salt to deposit on the surface.

During initial inspections of the survey area it was found that some areas contained more springs than others. The majority of these spring areas where to the west of the Hovells Creek Landcare Group. These western springs had varying EC levels ranging from 0.3 dS/m to 1.2 dS/m with a ground water bore (14 metres deep) in this area registering 3.3 dS/m (SWL 5 metres). Springs along Hovells Creek registered 3.4 dS/m. Some creeks and springs from the eastern area registered 1.4 dS/m and 4.1 dS/m respectively.

Periods of low evaporation and high rainfall have a higher chance of increasing groundwater levels, more water will move through the soil profile to enter the ground water system. These periods are dominant for the winter months in the Cowra region, with rainfall varying between 50 mm to 70 mm per month. During these periods vegetation growth is low, so even more water will be able to infiltrate the ground water system.

ELECTRO-MAGNETIC INDUCTION SURVEY

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Interpretation of EMI Survey Maps

It should be noted that these are not salt maps, but are maps that represent another layer of information for use in farm management. They reflect the apparent bulk conductivity, not actual amount of salts in the soil. Map Interpretation based on the variation in readings obtained not the values themselves.

The EMI maps show low conductivity areas as blue to green, inferring that these areas are low in salts, water or have a sandy texture. Usually these are hills and quarries, they can also be geological barriers. High conductivity areas are shown as red to pink, inferring high in salt and/or water levels and/or have dense clay textures. Usually they are present in low areas adjacent to creeks or flow lines or groundwater barriers (railways, geological features).

The usual pattern that should be seen is a gradual change from low conductivity (blue) to high conductivity (pink) and is consistent for most creeks and flow systems. For unusual distribution of colours and unusually high readings validation has to carried out to identify any salinity symptoms, such as bare areas, salt crystals, salt tolerant grasses (couch, sea-barley grass), dead and dying trees (from tips of branches).

Results of the EMI Survey

The majority of the survey area was granite outcropping and the patterns seen on the EMI survey map (see Figure 2) show low conductivity for areas that where within these granite outcrop (surrounding hill and slopes). The majority of the western outcropping had higher conductivity than the northern and eastern outcropping. The highest conductivity readings where found along the flow lines, creeks and Hovells Creek itself.

The high conductivity areas are largely elongated (north/south trending) and where identified as mainly pink areas, these areas are surrounded with areas of red (Figure 3). The majority of the high conductivity is in the western part of the survey map, which is consistent with the saline and waterlogging hazards.

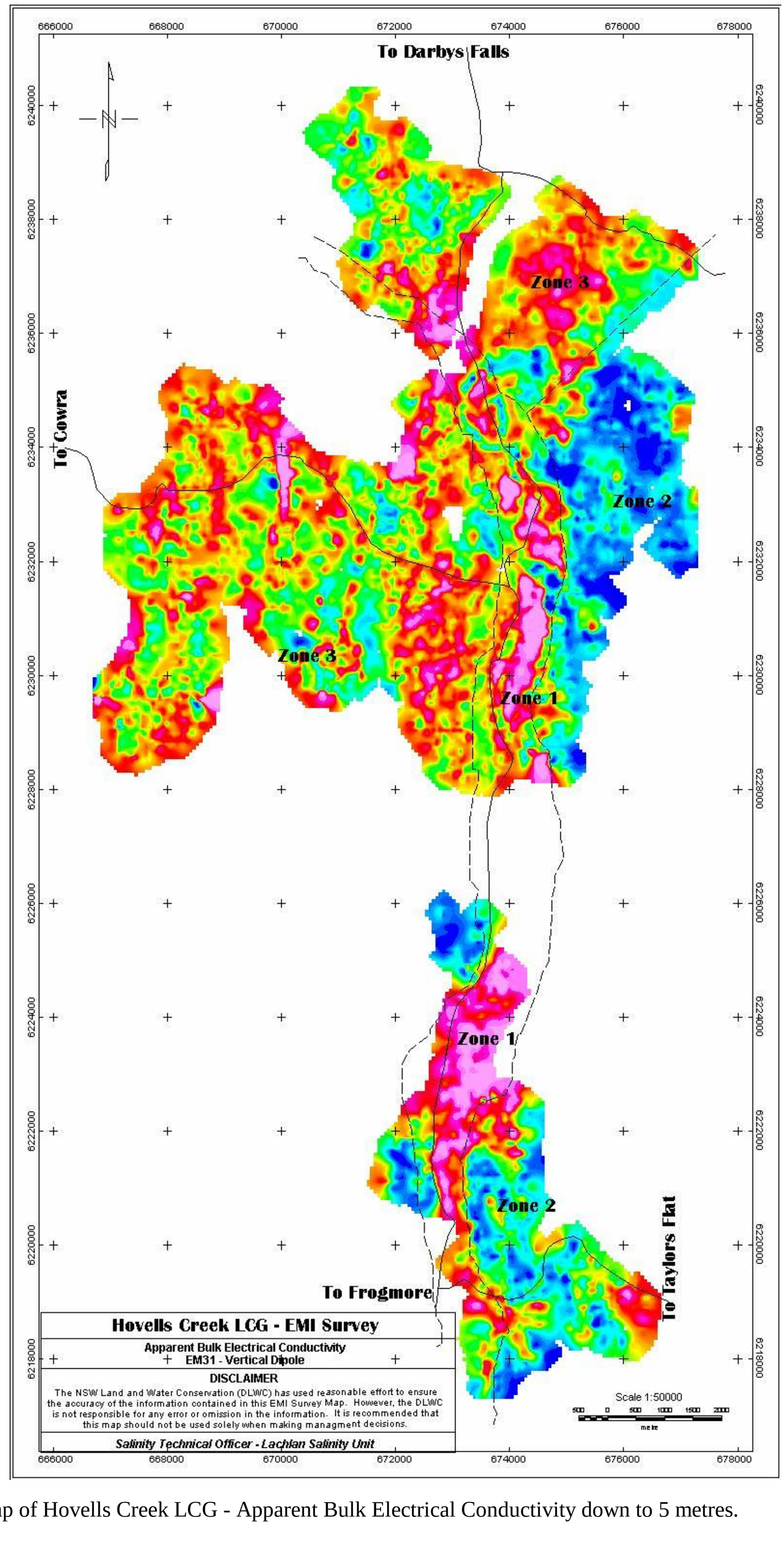

Figure 2. EMI Survey map of Hovells Creek LCG - Apparent Bulk Electrical Conductivity down to 5 metres.

ISSUES AND WHERE TO FROM HERE

Dryland salinity is a problem caused by a change in the water balance in the landscape. Over clearing for agriculture and development has meant that less water is used by plants in the landscape and adds to groundwater. A general way to look at water-use is to compare it to the leaf area of plants in the landscape. The higher the leaf area of plants in a landscape the higher the water use.

The Hovells Creek LCG survey area was split into three main zones, determined by using geology, regolith and the EMI survey. These zones consisted of:

Zone 1 – "Hovells Creek River Flats"; consisting mainly of transported sands and clays within the flooding zones of the Hovells Creek itself. These areas are more prone to water logging and salinity.

Zone 2 – "Slightly Weathered Granite"; consisting mainly of rocky outcrops and hill slopes to the east of Hovells Creek. Little or no springs where present during the survey.

Zone 3 – "Moderately Weathered Granite"; consisting of rocky outcrops and deep valleys. This area has many springs and spring fed creeks.

Within each of these zones several issues can be identified, but the Zone 1 issues will be tailored more towards saline agronomy. Zones 1 and 2 will have similar management recommendations, these issues are highlighted further.

ISSUE - Management of Saline Discharge Areas: Wet, Salty and Bare Soils

- Isolate area by fencing - use EM map with technical interpretation to define boundaries and potential spread of areas.
- Establishment of salt tolerant pastures. Methods of establishment are detailed in Salt Action Dryland Salinity Book 4: Productive Use of Salt Affected Land. Best species and mixes can be isolated by a simple soil salinity test and would include tall wheat grass, puccinellia, Australian phalaris, strawberry clover and fescue.
- Pastures should be managed for greatest feed value and water use. Avoid pasture becoming too tall and rank or being eaten out and having low leaf area.
- Management of these pasture areas would include crash grazing, rotation grazing and baling for fodder.
- Salt tolerant trees are very useful on these sites. Experience has shown that trees and pastures should be kept separate to allow correct management of both. Double fencing or electric fencing would be the best option to achieve this.

ISSUE - Management of Native Pasture: High Recharge Areas

- Management of native grasses on rocky areas. Hill tops and rocky slopes.
- Aiming at healthy pastures with a leaf area that enables plants to use available water.
- Increasing water use through greater variety of grasses.
- Establishment of effective management of summer active species to make use of rainfall.
- Rotation grazing to manage native grass pastures.

ISSUE - Management of Improved Pastures

- Pastures should be established and managed for greatest water use. They should have the ability to vigorously use moisture that is available to them.
- Pastures should be managed to have good vigorous pasture growth at all times. Rotation grazing and constant pasture assessment should be practised.
- Soil problems should be isolated and treated through correct and adequate fertiliser application, correction of soil acidity problems through lime application.
- Consider a mix of pastures at paddock scale and property scale to have year round water use. Variety of pasture species should be balanced with the ability to manage the areas to promote water use.
- Work in Victoria has shown that well managed perennial pastures have the ability
- To control recharge up to 600 mm rainfall. Trees and native vegetation are need in the Garland area.

ISSUE - Trees and Native Vegetation

- Establishment of trees and shrubs on contours throughout the landscape.
- Trees should also be used on and around discharge areas indicated by EMI survey maps.
- To have any significant water use effect with trees a minimum of 5 rows is recommended.
- Aiming at mix of species with Trees shrubs and understorey plants (acacias, eucalypts, and melaleucas). Various water use characteristics should be mixed together.
- Acacias are a good colonising or understorey plants and should be managed with a long-term view. This may include thinning at approximately 12 years.
- Variety of trees recommended for pest and disease resistance as well as a mix of water use characteristics.
- Deep ripping along fence lines prohibits lateral growth of tree roots and influence on crops and pastures.
- Large block planting's will be the best option in some areas as defined be EM survey and further geological investigation work. Salt and water tolerant species suitable for this area are listed in Salt Action Book 4 - Productive Use of Saline Areas.
- These areas should have a variety of different pastures and crops with the aim of constant high water use throughout the whole year. EM and geology maps will help to define these areas.

ISSUE - Soil Health, Structure, Nutrients and Acidity

- Soil health problems can be a major inhibitor to plant growth. This then has major impacts on the ability of vegetation to use water.
- Soil structure problems and hard pans or plow pans can be corrected through techniques such as deep ripping, agro plow use, and greater organic matter through stubble retention and late cool burning. These problems need to be addressed in a structured way. Advice should be sourced from either Ian Packer or Tim Gardiner.
- Soil acidity can be a major limiting factor in crop and pasture areas. Correct lime applications will correct this.
- Soil nutrients need to be managed through correct application of fertilisers.

KEY CONTACTS

NAME	POSITION/DEPT	TELEPHONE	AREAS OF INTEREST
Brett Butler	Agronomist NSW Agriculture	(02) 6342-1333	Pasture establishment and management. Cropping programs and management.
Kieran Hawker	Catchment Advisory Officer, DLWC	(02) 6341-1600	Erosion control, vegetation management, agricultural earthworks.
Ian Packer	Land management specialist Officer, DLWC	(02) 6342-1600	Conservation farming, cropping, soil management.
Darryl Cluff	Native Grasses Extension Officer DLWC	(02) 6377-1099	Native grass management and establishment.
Alan Nicholson	Salinity Investigations Officer, DLWC	(02) 6845-2488	Salt tolerant pastures, salt tolerant trees, sub-catchment salinity plans.
Guy Geeves	Research Officer DLWC	(02) 6342-1811	'Gambarra Project' companion planting of crops and pastures.
Andrew Wooldridge	Salinity Extension Officer, DLWC	(02) 6341-1600	Salinity identification and management.
Nik Henry	Salinity Technical Officer, DLWC	(02) 6341-1600	EM Survey and interpretation.
Rob Muller	Salinity Hydrogeologist DLWC	(02) 6341-1600	Geology and groundwater.
Justin Hughes	Technical Officer	(02) 6342-1811	Neutron probes and soil moisture measurements.
Bob Sly	Upper Lachlan Project Manager Greening Australia	(02) 63411-600	Fencing/vegetation incentives program. Tree establishment techniques and species.

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Muller R., Wheeler H. and Wooldridge A., 1998, "*Hovells Creek Dryland Salinity Investigation: Dryland Salinity Awareness Project",* Report No. CW GWS 99/002, Central West Salt Team, NSW Department of Land and Water Conservation, Cowra.

Cook, P.G. and Williams, B.G., 1998. *Electromagnetic Induction Techniques*, Series: the basics of recharge and discharge – part 8, CSIRO, Collingwood, 16 pp.

Geonics Ltd., 1992. *EM31 Operating manual*, GEONICS LIMITED, Ontario Canada, 13 pp.

Nicholl, C., Britten, R., Tassell, G. And Richardson, P., 1993*. Land assessment using electromagnetic induction*, CSIRO, Canberra, 17 pp.

APPENDICES

APPENDIX A- ELECTROMAGNETIC INDUCTION THEORY

EMI is a widely used method of estimating soil salinity levels, measuring how well the soil can hold an electrical current or the apparent Electrical Conductivity (ECa). ECa is determined by several soil characteristics and these include (Nicholl *et al* 1993):

1. Total amount of pore space in the 6-meter soil profile
2. The amount of groundwater or soil moisture filling the pore spaces
3. The salinity of the groundwater or soil moisture
4. Temperature of soil profile
5. The type and amount of clay in the 6-meter soil profile
6. The amount of organic matter in the soil

The units of measurement used for EMI surveys are conductivity units and are called siemens (S). The EM31 reads in milli siemens per centimetre (mS/cm). The electromagnetic current that a soil conducts can be related to the amount of salts present. ECa readings plotted on a map can be used to define recharge and discharge areas in a landscape. These maps coupled with geology can also help to distinguish between locally influenced salt sites and regionally influenced sites.

The EM31

The instrument used for the EMI survey was an EM31, which is operated by one person and measures the Electrical Conductivity of approximately the top three to six metres of ground. An advantage of using this unit is that the survey is quick and requires no ground disturbance.

Resolution of the EM31 is high, with changes of 5% being quickly determined. The instrument is capable of giving an extremely precise survey with information on small variations in the terrain. There are a number of things which can influence the readings of apparent conductivity; clay content, soil moisture, soil salinity, geology, as well as interference. The instrument is relatively unaffected by fences, overhead power lines and other nearby metallic objects. The EM31 is sensitive to electric fencing and underground conductors such as large pipes and drums etc. Hence there is a real need for validation of EM survey results.

APPENDIX B- EMI SURVEY METHODS

The EM31 is calibrated on areas expected to produce low conductivity values. The area used to calibrate the EM31 for the EMI survey was on the upper slope of the southern part of the survey site. The AGM grid co-ordinates were 657100 E at 6256100 N.

Readings were taken every 2-4m along transacts spaced up to 20 metres apart, depending on geomorphology and field conditions. In areas where there was a higher probability of salinity occurring more readings were taken. To this extent the survey is subjective, however comparison with earlier grid style surveys shows good correlation. Regardless of sampling strategy it is important to obtain good ground coverage. This ensures the mapping program GEOSOFT Montaj has adequate data to produce accurate results.

Physical Survey

The EM31 is mounted alongside a 4WD motorbike using on a 50 mm PVC frame. Also mounted on the bike is a Trimble ProXR global positioning system (GPS), a Land Star MkIII differential GPS and the Asset Surveyor data logger. At each survey point an EMI reading is sent from the EM31 and stored with the position co-ordinates in the data logger. The data logger's memory is downloaded as required and the format of data altered to suit the GEOSOFT Montaj mapping system.

APPENDIX C- MORE ABOUT EMI SURVEY MAPS

Electro Magnetic Induction (EMI) is a widely used method of inferring soil salinity levels. The Geonics EM31 can sample 'soil conductivity' down to 6 m (18 ft) below the surface, but this depends greatly on the properties of the soil layers being surveyed. In some areas, especially ridges and crests, geology can be the main influence of readings obtained, the accurate location of the data collected is determined using a Trimble Differential GPS unit (± 1 m).

The EMI survey map is generated using the mapping program GEOSOFT Montaj, which compares only the EC_a readings collected from the survey site, it shows the site divided into 40 classes from the least conductive to the most conductive. This gives an indication of the distribution of soil texture, soil moisture and cyclic salts from around the survey site.

These maps are useful in giving an indication where potential problems lie and an indication of the potential spread of current saline sites. It is important to understand the distribution of patterns on EMI survey maps to distinguish between differing soils types or recharge and discharge zones. ECa readings usually vary between two extremes (Geonics, 1992):

Low conductivity areas are blue and green, inferring that these areas are recharge areas and are generally light textured, dry and free of cyclic salts. In some cases these areas can be discharge sites, but have little or no cyclic salts in the groundwater.

High conductivity areas are red and pink, we infer that they are mainly discharge sites and generally heavy textured, moist and contain high amounts of cyclic salts. When there are different geologies within a survey area the readings obtained for crests and ridges can vary between low for shale and high for basalt.

Because the EM31 takes an average reading from the surface to 6 m, the maps cannot predict how far below the surface ground water will occur. Should there be need for further information on the hardware and/or software used please contact:

EM31 METER	**TRIMBLE GPS**	**GEOSOFT**
Geoterrex Pty Ltd	Ultimate Positioning	Software Retail
7-9 George Place	PO Box 291	Suite 24, 32 Richardson St
ARTARMON 2064	PENNANT HILLS 2120	WEST PERTH 6005
Ph: (02) 9418-8077	**Ph:** (02) 9484-9293	**Ph:** (08) 9322-8122
Fax: (02) 9418-8581	**Fax:** (02) 9875-3904	**Fax:** (08) 9322-8133