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East Ballidu Catchment Report

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EAST BALLIDU CATCHMENT REPORT

A National Soil Conservation Project

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1. SUMMARY

It will require the total co-operation of all the members of the Soil Conservation District to remedy the area's problems.

The first priority is for the control and better use of water on the recharge areas. The wheat/wheat/lupin rotation at present offers the best economic option. Lupins are well suited to the areas of lighter land. If lupins are planted on waterlogged soils or otherwise unsuitable soils, problems will arise and perhaps prejudice their use on the widespread suitable areas.

The use of trees below rocky outcrops is an important measure to prevent excessive recharge of the deeper aquifers. Where trees already exist they need to be fenced to allow them to regenerate. Grants are now available for the fencing of remnant areas and is one line that the group members should vigorously explore. All remnants of bush and forest should be indentified and protected in the catchment.

In general the planting of trees for shade and shelter, windbreaks, on wind blown areas and on the fringes of salt land will play an important role in water use. The number of trees quoted in the catchment plan refer only to areas where a clear and obvious need exists. Some farms without salt land or serious wind blown areas will still require trees for windbreaks, non productive land and the general provision of shade and shelter around buildings and yards. Recognition of this need suggests that most farms would require 15,000 or more trees over and above those specified for areas of specific land degradation.

The number of trees required for planting on wind blown area is uncertain at this stage, For example of the suitability of tagasaste and the management regime necessary to achieve production from tagasaste areas is still developing. Tagasaste needs to be cut for fodder, involving some outlay in machinery and labour, this may not suit the management trend, which is fully committed and geared to maximum production from the labour resource.
If the tagasaste is not harvested, the advantage is lost and it would be better to plant trees with a maximum water use.
In respect of the wind blown areas, many people feel that they can be controlled by management, such as minimum tillage, incorporation of stubbles and planting of blue lupins while others advocate natural re-vegetation without planting trees or shrubs. Sometime in the future when the production and management of tagasaste has been demonstrated, a clearer picture will emerge.

Although a great deal of work has already been done, additional water control by contour and grade banks is an urgent necessity. This work has a high priority and should precede the planned drainage works.

It is significant that the areas incurring most of the runoff from the higher eastern end of the catchment have been contoured while the areas generating most of this water either remain to be done or have in adequate banks. This situation requires urgent redress. It cannot be too strongly stressed that this work is a prerequisite to any further drainage. Some farmers on low lying areas have used water control structures to improve their salt land and now believe they have beaten the problem. I cannot share their optimism, until such time as the work has been done on the higher parts of the catchment as water table fluctuations could quickly reverse their good work. There is insufficient information on regional water table trends with time and seasonal variations, to make reliable prediction. It is recommended that the East Ballidu Land Conservation District requests a research project to determine regional water table trends and the effect if any of the more highly metamorphosed geology of the western end on the salinity and drainage problems in the catchment.

There is some flexibility in the type of banks farmers use. Unless suitable water ways can be found level banks must be used.

Further down the slopes where waterways can be developed, grade banks or broad banks are suitable options. It is important that banks be built to the specification later in this report.

Protective Fencing of Salt Land, Wind Eroded Areas or Other at Risk Land

The fencing of degraded areas for protection will be a major undertaking for the members of the soil conservation district. The effectiveness of this project will be enhanced if due consideration is given to the following factors.

Fencing of salt land

Allow enough non saline land in the enclosure to enable the planting of the less salt tolerant, but higher water use trees. Envisage contours when fencing and if possible fences should be sited so as not to cut off low lying salt from land, which at a future date may mean moving the fence. Where paddocks are to be planted to salt tolerant fodder plants, plan water supplies at the same time.

Fencing Off Wind Eroded Areas

Efforts should be made to site the fence on stable soil, stock movement along fences will initiate wind erosion and may produce an eroded area adjacent to the fenced off area.

The Land Management Plan

The farmers in the soil conservation district were visited, planning was done using aerial photography as a base. There were varying degrees of acceptance of the idea of planning around the land management unit, the planning was carried out within these constraints. The East Ballidu Soil Conservation District should encourage its members to adopt the land management planning philosophy.

Drainage

The intermittent flooding of paddocks and roads is causing serious degradation. It has been shown that paddock flooding causes a rise in the water table (Hydrol. Investig.). Subsequent capillary rise and evaporation deposits salt.

There are strong arguments in favour of a complete drainage system. A central drain is planned into which individual farmers can plan their drainage systems.

Land Susceptible to Wind Erosion

The definition used i.e. "Deep yellow sand which by its position in the landscape and aspect, is liable to erode, shows signs of wind deflation at present or evidence of past activity". There is an estimated 800-900 hectares out of approximately 17,000 ha of this soil type which is endangered.

It is necessary to clarify the situation by saying that most of the land on the catchment will blow, given the right situation, the land mentioned as endangered is in a much more difficult management category.

Summary of Works Needed and Cost Estimates

Length of fence required to fence off salt land, rocky areas, drains and waterways	254 km
Estimated cost of fence materials, no labour included @ $1,000/km	$254,000
Number of trees required for the saline, rocky, drains and waterway areas	166,000
Length of fencing required to fence off wind erosion areas	27 km
Estimated cost of fence materials, no labour included @ $1,000/km	$27,000
Area susceptible to wind erosion	864 ha
Estimated length of contour banks required (i.e. level banks)	206 km
Estimated cost of construction @ $900/km	$183,000
Estimated length of grade banks or broad based banks	40 km
Estimated cost of broad based banks at $700/km	$28,000
or	
Estimated cost of grade banks @ $400/km	$16,000
Total cost using broad based banks	**$492,000**
Total cost using grade banks	**$480,000**

There is an additional cost for drainage.

Some Brief Remarks about the Demonstration Areas

These areas have been covered in detail in Appendix 3. This is a progress report following an inspection on 20/1/1989. For location diagrams see Appendix 3.

1. Salt bush management demonstration on Campbells property

(a) A small area was planted using seedlings and the tree planter. Most of the seedlings were too small for the tree planter and as a result were poorly planted. The well grown seedlings have established well and the results suggest that well grown seedlings can be successfully planted with the tree planter.

(b) Ten hectares were seeded by a contractor using the Mallen seeding method. The seed was planted under ideal conditions during the first week in August. The site was well drained, moderately salt land. The rainfall in June was 82 mm, July 61 mm and August 61 mm. Despite an ideal season the germination was very poor and few seedlings survived on the areas. This rather expensive exercise casts serious doubt on the viability of this method. Possibly the seed may have been very poor, a very high hard seed content may result in a germination next year, but this is merely speculation and cannot detract from the failure in 1988. The cost of the project was $160/ha.

2. Saline seepage area

This area on Whyte's farm was planted on a cool cloudy day after 2.5 mm of rain on July 6. The following trees were planted, River Red Gum, Tasmanian blue gum, sugar gum, tuart, flat topped yate, Casaurina and a few tree medic.
About 400 trees were planted.

With the exception of some of the tuarts, which were very poor seedlings, there has been a high success rate. The most promising looking tree at this stage is the Tasmanian blue gum. About 60% of the Tree Medic seedlings have survived.

3. Other tree plantings

The extent of success was governed to a great degree by the quality of the seedlings, the surviving trees are well grown.

The demonstration sites deal with the most likely initiatives for the Ballidu area, it is by no means exhaustive. For example, puccinellia still has a useful role and may be used on dry salt land areas, e.g., perennial species such as couch, kikuyu, tall wheat grass and strawberry clover can effectively be used on sand seepage areas where salinity is mild and the area remains moist all the summer. Areas around soaks may benefit from being fenced off and planted to perennial species, apart form being good sheep feed, the pasture prevents evaporation and the encroachment of salt around an otherwise good water supply.

Soil Conservation Priorities

The members of the soil conservation district will need to establish implementation priorities.To complete the contouring of the upper catchment would be an early objective.

Fencing off of saltland, rock areas and windblown sands have a high priority.
Tree planting of these areas should be accomplished soon after fencing. The contouring, fencing and tree planting should proceed concurrently. Drainage is best left until the water use and retention treatments are in place on the slopes.

It is expected that the entire project will be spread over a number of years however it is essential to set finite goals based on the shortest timespan within the constraints of finances.

2. PROJECT OBJECTIVES

The East Ballidu Land Conservaion Catchment Plan was a project shared between the farmers, NSCP, local Government and the Department of Agriculture to:

(i) Control waterlogging and salinity.

(ii) Prescribe land-use methods to sustain profitability, prevent soil loss and reduce ground water recharge by maximising water use.

(iii) Demonstrate and promote appropriate management methods and examine the financial ramifications of any proposed land use changes.

(iv) Provide land management plans defining broad land capability classes to be prepared for all the farmers on the catchment.

These plans specify land management options,such as, tree planting, salt land fencing, water erosion control and drainage as is required on each farm.
This report provides farmers with information to further develop their farm plans.

2.1 Survey methods

1. Literature search and aerial photo interpretation.
2. Field survey to delimit landforms and soils vegetation association.
3. Discussions with farmers to establish soils associations representing land management units.
4. Drilling bores to assist with characterisation of the demonstration areas.
5. Selection and survey of demonstration areas.
6. Monitor bores to determine water table characteristics.
7. Measure stream flow to assess drainage requirements.
8. Computor technology to (Department of Agriculture expertise)
   (i) Calculate runoff water yields from 17 subcatchments.
   (ii) Produce mapping as required.
   (iii) Study land use alternatives.
   (iv) Characterise saline areas.
   (v) Design drains and culverts.
9. Visit farmers to gather local information and prepare individual land management plans.
10. Hydrologist to complete a geophysical survey of the trial areas. Section 6.2
11. A computer catchment yield study by Ed Hauk and drain design by Ruhi Ferdowsian. Section 6.3
12. A financial assessment of land use alternatives using records kept by local farmers. Section 6.1

3. EAST BALLIDU CATCHMENT

3.1 Location

The East Ballidu Land Conservation District (EBLCD)
The EBSCD was gazetted in February 1986. Ballidu is situated approximately NNE from Perth, Western Australia on the Moora Western Australia 1:250 000 map series 1501SH50-10, longitude 116degrees47' east and latitude 30degrees36' south. The area lies mostly east from Ballidu (see locality map)

Climate
The area experiences a mediterranean type climate with hot dry summers and cool wet winters. The soil conservation district lies in the 320 mm zone.Summer thunderstorms occur sporadically often resulting in intense rainfall events.

3.2 Development History

Farming enterprises
Grain production is carried out using wheat lupin and pasture wheat rotations. Wool production is a minor enterprise.

History and development of the area
Settlement took place on the medium to heavy soil types around 1910. The 1950's saw large areas of the lighter land cleared and cereal production was greatly increased. From then on the development of water logging and salinity was observed on the drainage lines and lower land. At the present time most of the low lying land will not produce an economic crop of wheat.

Area of the East Ballidu Soil Conservation District
The East Ballidu Soil Conservation District is a large catchment system occupying some 50,000 ha.

Drainage
The drainage runs from east to west and discharges into a chain of lakes forming part of the Mortlock system, finally ending in the Avon River. The system is sluggish and characterized by areas of saltland wherever the refief is low.

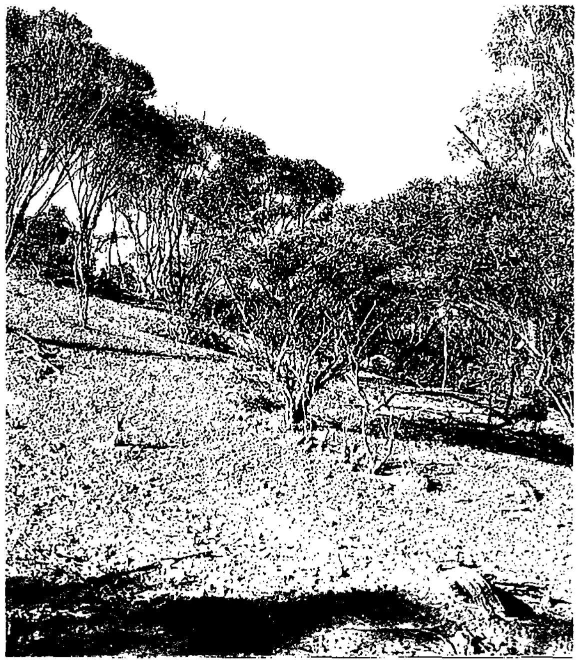
The catchment divides of the EBLCD run parallel with a central drainage system, this is fed by 17 subcatchments. The stream channel pattern is of a tributary nature.

3.3 Land Management Units

Landscape units

1. The granite outcrop unit, represents the most elevated areas within the system. The large area of exposed rock generates considerable run off during rainfall events. PHOTO No. 1.

1. Rocky outcrop areas cause excessive rainfall runoff.



2. Breakaways produce sparse vegetation excessive runoff may cause water erosion

2. The lateritic breakaway unit

These usually run east and west and are prominant features throughout the land system. On the depositional side are gravels and sandy gravels. The erosional side, mottled and pallid zone clays have been exposed by truncation of the upper sand and gravelly horizons. Movement of water through the exposed pallid zone layer causes generally, small saline areas to appear in these soils. PHOTO No. 2

3. The central drainage unit

This is a broad meander plain, grades are level @ 1%. Stream channel development is incipient. Early settlers selected land on this unit, a 15-35 cm deep, leached horizon of sandy loam was easy to cultivate and produced good crops. Most of this area is mild to moderately saline and waterlogged, closer to the lakes, severe salinity is apparent.

4. The lake unit

Is situated on the west end of the catchment and eventually discharges into the Mortlock system. This only occurs in the wettest years. The lakes are linked by samphire flats. The complex of flats and lakes has a buffering effect on the intensity of the stream flow from the more elevated parts of the catchment.

Land management units

A land management unit is a practical way of grouping soils according to the way they would be managed for optimum results, the district groups may be as follows:-

Summary Sheet

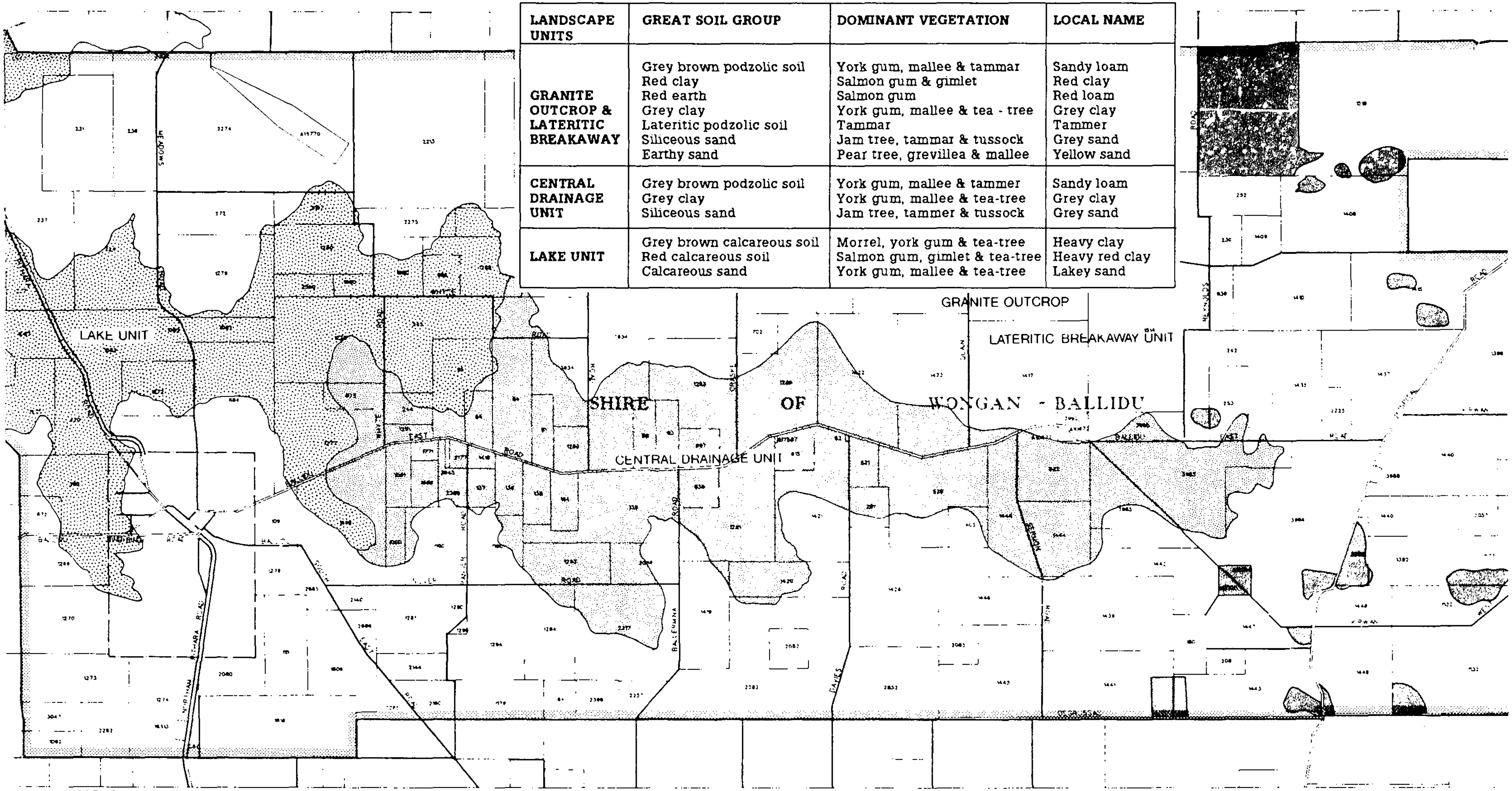
The soil classification is suggested as being easily related to a land management concept

Unit	Great soil group	Dominant vegetation	Local name
GBK	Grey, brown calcareous soil	Morrel, York gum and Tea-tree	Heavy clay
RK	Red calcareous soil	Salmon gum, gimlet Tea-tree	Heavy red clay
GC	Grey clay	York gum, Mallee and Tea-tree	Grey clay
RC	Red clay	Salmon gum and Gimlet	Red clay
RE	Red earth	Salmon gum	Red loam
GBP	Grey brown podzolic soil	York gum, Mallee and Tea-tree	Sandy loam
LP	Lateritic podzolic soil	Tammar	Tammar
GS	Siliceous sand	Jam tree, Tammar and Tussock	Grey sand
KS	Calcareous sand	York gum, mallee and Tea-tree	Lakey sand
ES	Earthy sand	Pear tree, Grevillea, Acacia and Mallee	Yellow and Deep Yellow Sand
ES/WE	Earthy sand	Acacia	Wind blown
S/A		Samphire and saltbush	Salt affected regardless of soil type

Land Management Units and Characteristics

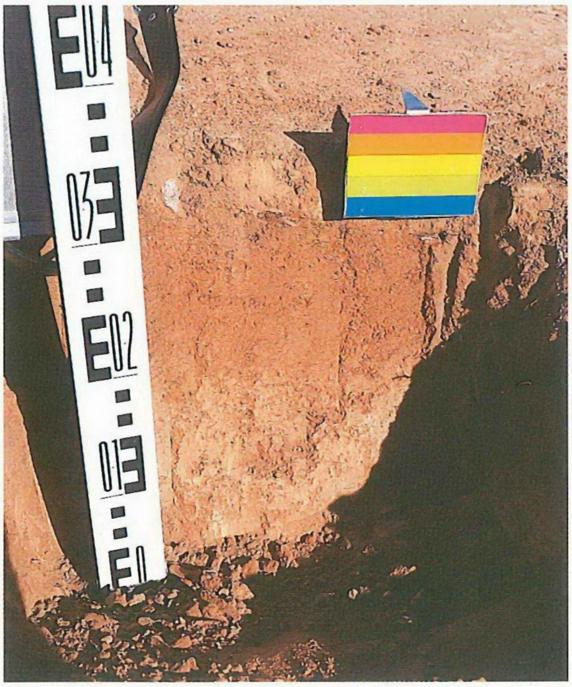
Land Management	Characteristics	Management practice
GBK and RK Grey brown calcareous soil and red calcareous soil	Associated with gilgai Subject to cracking. Powdery when dry. Sticky when wet. These are high pH soils	Suitable for medics Unsuitable for lupins. Difficult to cultivate when wet. Subject to wind erosion if fallowed. Fertilizer application 30-35 kg/ha DAP.
RC and GC Red clay and grey clay	Maybe hard setting soils. Top soil may have acid trend, with sub soils alkaline	If soil structure has declined gypsum may be necessary. Unsuitable for lupins. Fertilizer application 30-35 kg/ha DAP.
RE, GBP, LP, GS Red earth, grey brown podzolic, and grey sand	These are loamy soils with a leached topsoil profile, the topsoils are are coarse textured. The soils are generally neutral to slightly acid.	Where well drained they will grow lupins. These soils are easily managed. Fertilizer rates 35-40 kg/ha DAP with 40 kg/ha of urea at seeding time.
KS Calcareous sand	A soil associated with lake systems.The pH is high.	The management is as for RE, GBP, LP and GS except being a high pH soil, medics would do well on it.
ES and ES/WE Earthy sand and earthy sand liable to wind erosion.	The yellow sands are underlain with clay substrata. The soils are acid. The deeper soils, subject to wind erosion are well leached and less fertile.	These soils are suited to lupin production in rotation with wheat. Direct drilling is indicated to avoid wind erosion. The more susceptible soils need to be fenced off and planted to, cereal, rye, blue lupins or perennials such as tagasaste or wattle. Fertilizer application 45-50 kg/ha of DAP with 40 kg/ha of urea at seeding time.

The above groupings would represent local practice today. Future changed landuse may require more specific interpretation and so the soil units have been individually mapped in the land management plans.

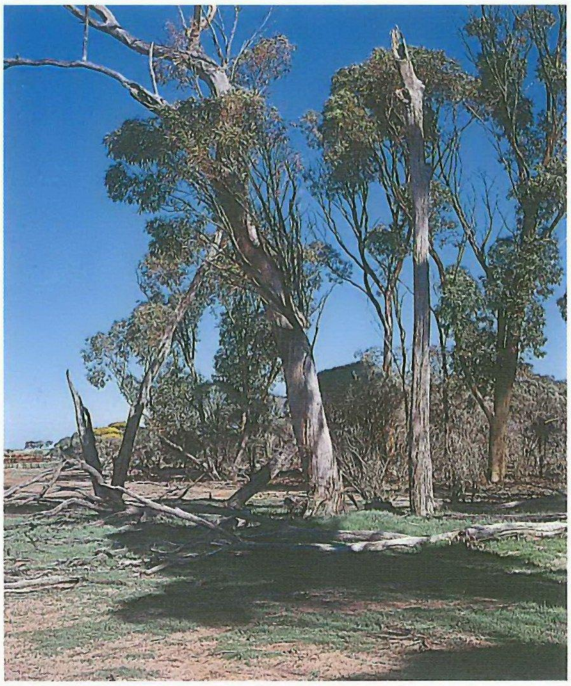


LANDSCAPE UNITS	GREAT SOIL GROUP	DOMINANT VEGETATION	LOCAL NAME
GRANITE OUTCROP & LATERITIC BREAKAWAY	Grey brown podzolic soil Red clay Red earth Grey clay Lateritic podzolic soil Siliceous sand Earthy sand	York gum, mallee & tammar Salmon gum & gimlet Salmon gum York gum, mallee & tea - tree Tammar Jam tree, tammar & tussock Pear tree, grevillea & mallee	Sandy loam Red clay Red loam Grey clay Tammer Grey sand Yellow sand
CENTRAL DRAINAGE UNIT	Grey brown podzolic soil Grey clay Siliceous sand	York gum, mallee & tammer York gum, mallee & tea-tree Jam tree, tammer & tussock	Sandy loam Grey clay Grey sand
LAKE UNIT	Grey brown calcareous soil Red calcareous soil Calcareous sand	Morrel, york gum & tea-tree Salmon gum, gimlet & tea-tree York gum, mallee & tea-tree	Heavy clay Heavy red clay Lakey sand

MAP OF EAST BALLIDU LAND CONSERVATION DISTRICT SHOWING LANDSCAPE UNITS

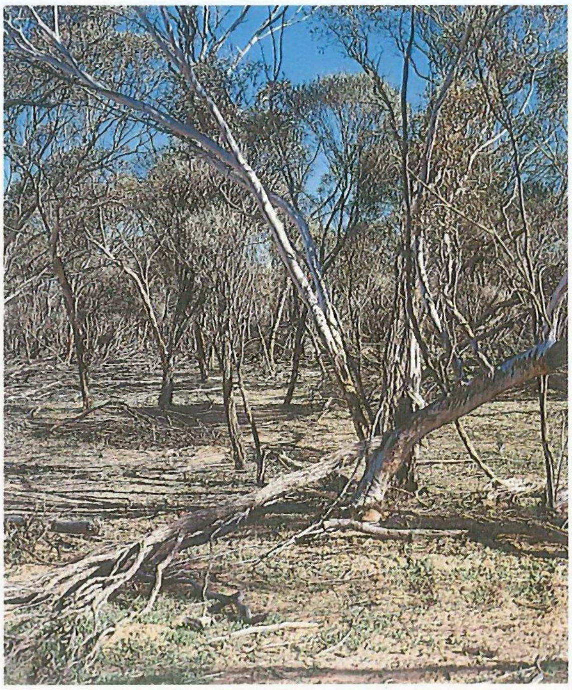


3. A red clay profile.

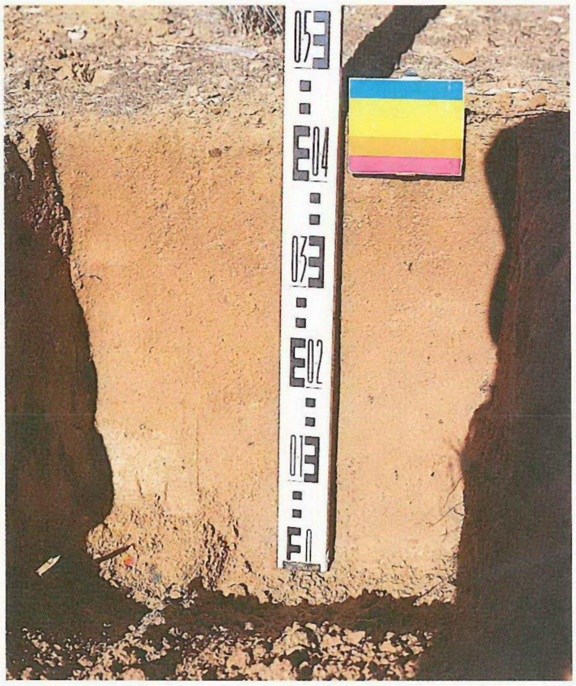


4. Vegetation associated with the red clay .

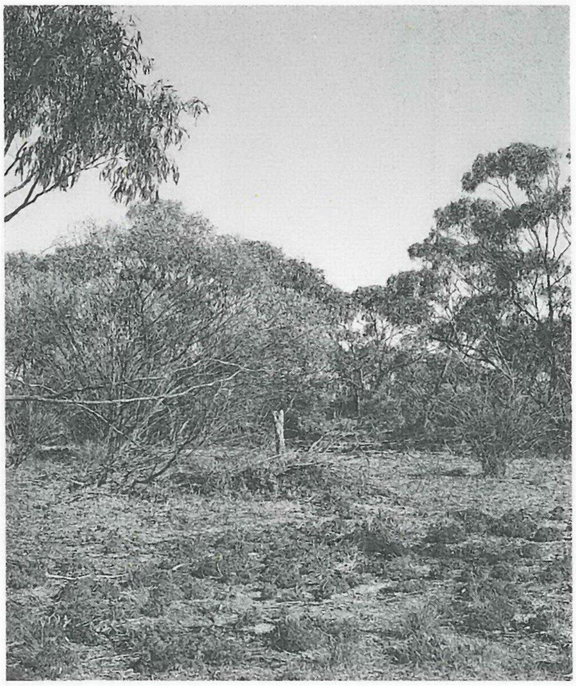
5. A grey clay profile.



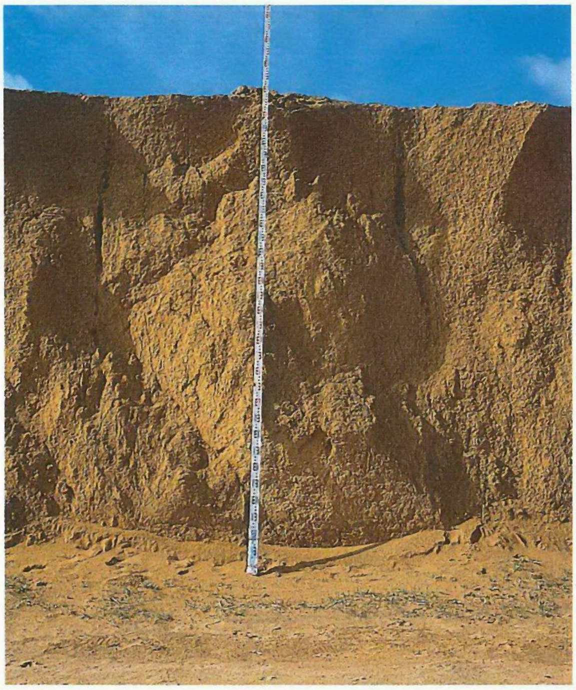
6. Vegetation associated with the grey clay.



7. The grey brown podzolic soil profile.



8. Vegetation associated with the grey brown podzolic soils.



9. A deep sandy soil profile.

10. A lateritic podzolic soil profile.

4. LAND DEGRADATION PROBLEMS AND LAND MANAGEMENT RECOMMENDATIONS

4.1. Wind Erosion

Wind erosion will occur on any of the EBLCD soils when they are heavily grazed. With better livestock management and by retaining stubble on the deeper yellow sands it should not be difficult to control. As a principle the deep sands would be better fenced off and allowed to regenerate or planted to deep rooted perennials. Early seasonal cultivation of this land will blow in a light wind.

4.2. Water Erosion

Water is an agent in causing soil erosion. Soil erosion occurs on all soil types in the district, some of the lighter soils, have a non wetting tendency, run water during storms causing erosion. Some of the clay soils are highly dispersive and will form deep gullies.
PHOTO No. 12.

11. Severe erosion on highly dispersive clay soils.

4.3. Saline Areas

(1) Flooding and waterlogging result in salinity. As a result of the farming activities most of the landscape has been cleared. Large areas of heavy land, together with numerous rock catchments on the most elevated north eastern end of the catchment generate large volumes of runoff, some as overland flow and some reaching deeper aquifers through recharge areas. The coarse sandy soils at the foot of the rocks and the large areas of lighter soils act as efficient recharge systems.

The areas of natural drainage runs east to west centrally down the catchment,and is fed by 17 subcatchments. The gradients are low resulting in sluggish drainage.
Runoff water concentrates here and makes its way in a broad relatively shallow stream to the lakes. Large volumes of water flow following moderate falls of rain, for example following 34 mm of intense rain, the flow channelised at Davies road was estimated at 3.22 m^{3}S with a channel velocity of 0.625 mS. PHOTO No. 12

Water from deeper aquifers creates a positive upward head along parts of the drainage line. This water is very saline and contributes to the salinity problem.

This area is usually waterlogged during the winter and grows mainly samphire and saltbush. The soils are mostly only moderately salt and the topsoil has not been washed or blown away. In addition to samphire, the better drained areas grow cape weed and cluster clover, notably on the tops of furrows with deposition of salt obvious in the furrows.

Waterlogging and salinity runs back up the lateral drainage lines, with some isolated occurrences higher in the landscape.

(ii) Sandy seeps water falling on the recharge areas, follows clay or rock strata downslope in the depressions, frequently the strata shelves towards the surface and the rising water produces a seep area, which is initially waterlogged, but later may become saline.

If this water can be used either for livestock or by trees, the problem can be averted. Inadequate road floodways and culverts add to the problem of paddock flooding. PHOTO No. 13.

12. Flooding at Davies Road following heavy rains on the rocky catchment areas

13. Damage to a flood way following one intense rainfall event.

4.4 Recommendations

Trees

Over recent years there has been a greater awareness of the value of trees in the landscape. Most farms would benefit from the planting of trees.
Selection of trees for the dry wheatbelt area has been made difficult by the limited number of reliable species grown by nurseries.
The following list, though by no means comprehensive will provide a number of trees known to the successful under wheatbelt conditions.
The eventual selection of successful trees planted over the last few years will to add the list.

Native trees are valuable provided they are planted in their correct environment, rising water tables have killed out many indigenous species in recent years.

The tree planting experience over the 1988 season at East Ballidu has shown the tree planter has not been successful in low lying areas as the soil is left in a shape conducive to waterlogging. It is also worth noting that unless the tree seedlings meet an acceptable size, the tree planter cannot successfully plant them. Farmers are urged not to accept seedlings unless they meet the criteria required for successful planting.
In the East Ballidu Soil Conservation District trees should be planted for the following purposes:

Windbreaks
Strong winds cause problems almost every year.

- (i) Soil erosion occurs on soils that have been heavily grazed.
- (ii) Sand blasting of your crops occurs to the extent that large areas may need to be reseeded.
- (iii) Hot dry winds at flowering time will reduce lupin yields.
- (iv) Cold winds and rain cause losses among freshly shorn sheep and lambs. Tree planting for dust abatement around mining and industrial towns in arid areas, demonstrates that dedicated effort can improve a windy environment

Trees to dry up seepage areas
Trees can be used with or without drainage to dry up seepage and prevent the development of salinity.

Trees to stabilize wind blown areas
Where a soil type cannot be managed by direct drilling and the retention of stubble, and particularly where crop yields are marginal, trees should be used to stabilize the soil. Productive plants, suitable for fodder or other purposes should be a first choice.

Trees around the fringes of saltland
Trees will dry the surface out and prevent deposition of salt by evaporation.
shearing sheds, and farm tracks improve the quality of life.

Tree planting and management
Trees should be ordered one season in advance to allow the nursery enough time to produce healthy seedlings.
On well drained land, trees will need to be planted as soon after the first general rains as possible, this will give them a chance to develop a root system before the summer.
On saline or waterlogged soils it is necessary to wait until the Spring time when the possibility of flooding and severe waterlogging has passed.
Wherever livestock are run the trees must be securely fenced until they are large enough to survive. Temporary or electric fencing can be used to reduce costs. With tree planting, weed and vermin control is necessary, protection from fire is important.

Trees for heavy land (Land management units, GBK, RK, RC and GC)

Common Name	Species
Wattles	
Western Australian Golden Wattle	*Acacia saligna*
Paper bark and tea trees	
Dryland tea-tree	*Melaleuca lanceolata*
Eucalypts	
Gimlet	*Eucalyptus salubris*
Swamp Mallet	*Eucalyptus spathulata*
Coral gum	*Eucalyptus torquata*
Others	
Kurrajong	*Brachychiton gregori*

Trees for loamy soils (Land management units RE, GBP, LP, GS and KS)

Wattles	
Western Australian Golden Wattle	*Acacia saligna*
Prickly wattle	*Acacia victoriae*
Jam Tree	*Acacia acuminata*
Paperbark and tea - trees	
Dryland tea tree	*Melaleuca lanceolata*
Sheoaks	
Western Australian Swamp sheoak	*Casuarina obesa*
Belah	*Casuarina cristata*
Eucalypts	
Dundas Mahogany	*Eucalyptus brockway*
Gungurru	*Eucalyptus caesia*
River red gum	*Eucalyptus camaldulensis*
Kings mill mallee	*Eucalyptus kingsmillii*
Kondinin Black butt	*Eucalyptus kondininensis*
York gum	*Eucalyptus loxophleba*
Gimlet	*Eucalyptus salubris*
Salmon gum	*Eucalyptus salmonophloia*
Salt river gum	*Eucalyptus sargentii*
Swamp mallet	*Eucalyptus spathulata*
Coral gum	*Eucalyptus torquata*
Wandoo	*Eucalyptus wandoo*
Shrubs	
Silver cassia	*Cassia artemisoides*
Fiery bottle-brush	*Callistemon phoenicius*
Others	
Kurrajong	*Brachychiton gregori*

Trees for sandy soils (Land management units ES and ES/WE)

Common Name	Species
Wattles	
Western Australian Goldenwattle	*Acacia saligna*
Black wattle	*Acacia rostellifera*
Prickly wattle	*Acacia victoriae*
Sheoaks	
Desert sheoak	*Casuarina deciusneana*
Eucalypt	
River red gum	*Eucalyptus camalulensis*
Tall sand mallee	*Eucalyptus eremophila*
Narrow leafed mallee	*Eucalyptus foecunda*
Others	
Lucerne tree, Tagasaste	*Cytisus prolifer*
Kurrajong	*Brachychiton gregori*

Application of trees to specific problems

The large granite outcrops on the north eastern end of the East Ballidu Land Conservation District act as a water catchment area. The coarse sandy soils at the base of the rocks act as an efficient recharge area.

The water shedding from the rocks makes a significant contribution to the district's problems.
Seeps occur further down slope. Bedrock throughout the whole catchment area is relatively shallow (usually less than 30 m), water leaches salt from the pallid zone clays above the rock and causes a salty aquifer in the main valley floors and in the lateral depressions leading to them.

As a part of the total water control strategy, trees should be planted at the base of the rock to use this water.

Suitable trees for the shallow soils at the base of the rock would be:

Common Name	Species
Western Australian Golden Wattle	*Acacia saligna*
Rock sheoak	*Casaurina huegeliana*
Gungurru	*Eucalyptus caesia*

Further out on the deeper soils plant:

River red gum	*Eucalyptus camaldulensis*
York gum	*Eucalyptus loxophleba*
Wandoo	*Eucalyptus wandoo*

Where the natural vegetation remains it should be protected by fencing.

Tree spacings and row spacings

On the shallow soils nearest the rock plant trees 3 m apart, rows 4 m apartand plant 4 rows.
Further out on the deeper soil plant trees 5 m apart, rows 6 m apartand plant 4 rows.

The depressions below the rocks should be planted first.

Trees on the fringes of saltland

Trees planted on the fringes of saltland will dry out the soil and prevent the spread of salt. The fencing of these areas will encourage revegetation which in turn will protect the soil surface. Even on severely saline and waterlogged areas, samphire will volunteer.

Where the surface is dried out there will be less evaporation and the deposition of salt will be reduced. Trees and grasses will use the surface moisture and also protect the surface from the effects of wind and water erosion. Wind and water erosion are important processes in the development of saline areas and must be controlled for the successful reclaimation of saltland.

On saltland not affected by waterlogging and flooding, saltbush and blue bush will grow. It is unwise to attempt to grow bluebush and saltbush on land which is bare and subject to waterlogging and severe salinity.

When planting blue bush or saltbush by seed, make sure the germination percentage is acceptable, seed can look good but be non viable.

The trees to plant nearest the salt land will be:

Western Australian swamp sheoak	*Casuarina obesa*
Kondinin blackbutt	*Eucalyptus kondininensis*

A general rule is to plant these on the barley grass adjoining the bare saltland. Next to these plant salt river gum (*Eucalyptus sargentii*) and the swamp mallet (*Eucalyptus spathulata*) next plant flat topped yate (*Eucalyptus occidentalis*) and beyond that on good land plant the river red gum (*Eucalyptus comaldulensis*), white gum (*Eucalyptus wandoo*) and York gum (*Eucalyptus loxophleba*). Shrubs such as the Firey bottle brush (*Callistemon phoenicius*) and the paper bark (*Melaleuca lanceolata*). The Western Australian Golden wattle could also be tried.

Naturally saltland needs to be fenced off to allow controlled grazing and perhaps the planting of salt tolerant fodder species or trees. There are two strategies here:

(i) To fence the area off for autumn grazing, rough up the surface if necessary and allow it to revegetate naturally.

or

(ii) Fence off and seed to saltbush, if a successful germination is achieved, this will increase production.

Saltbush should only be planted on well drained areas as they will not tolerate prolonged waterlogging. It is a good principle to achieve surface drainage on any saline area.
As the cost of establishing saltbush can be quite high, there is little point in planting it into a poor environment.

When saline areas are considered for grazing they need to be large enough to provide grazing for a reasonable flock size. Also the provision of good quality stock water for livestock grazing saltbush is essential. Small areas are better fenced off, planted to trees and left to revegetate.

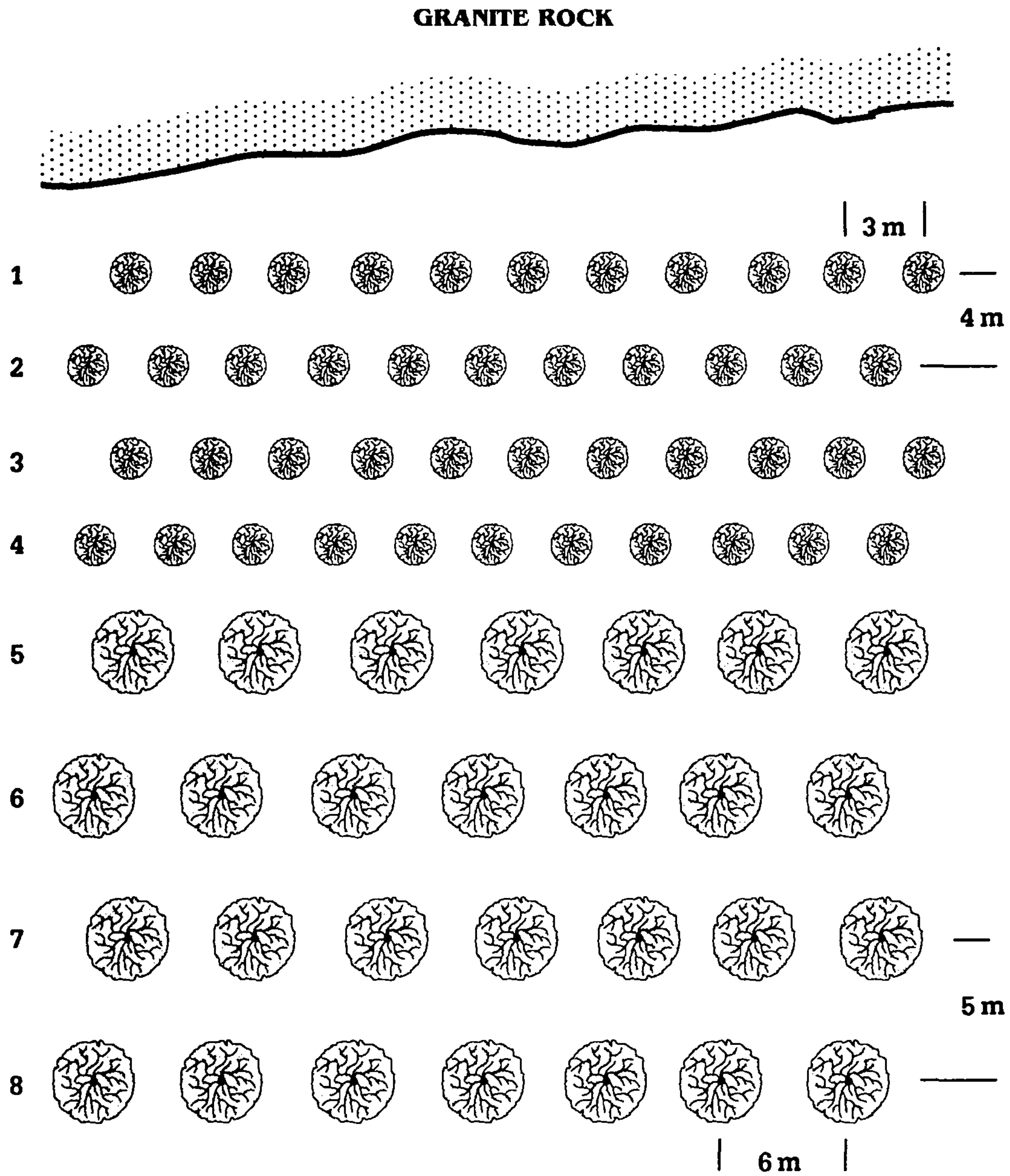
Deep rooted perennials on wind blown sands

Careful grazing control, together with the direct drilling of crops into the stubble will

SPECIES & POSITION OF PLANTING RELATIVE TO SALINE AREA

	TREES	SHRUBS & SMALL TREES	GRASSES & CLOVER
LAND NOT SALINE TREES PLANT TREES VITH HIGH WATER USE	EUCALYPTUS LOXOPHLEBA EUCALYPTUS WANDOO EUCALYPTUS CAMALDULENSIS EUCALYPTUS OCCIDENTALIS EUCALYPTUS SPATHULATA	ACACIA SALIGNA CALLISTEMON PHOENICUS	
BARLEY GRASS SALT BUSH & SALT TOLERANT TREES WILL GROW HERE	EUCALYPTUS SARGENTI EUCALYPTUS KONDININENSIS CASUARINA OBESA	MELALEUCA LANCEOLATA	MEDICAGO TRUNCATULA (BARREL) MEDICAGO POLYMORPHA CV SERENA (BURR) CYPRUS PARABENGA (APHID RESISTANCE) TRIFOLIUM GLOMERATUM
SEVERLY SALT LAND BARE SAMPHIRE WILL GROW HERE	SALT BUSH & BLUE BUSH SAMPHIRE	SALT BUSH & BLUE BUSH SAMPHIRE	PUCCINELLIA SAMPHIRE

TREE SPACING DIAGRAM FOR PLANTING TREES
BELOW A GRANITE ROCK



TREE RECOMMENDATIONS

ROW 1,2,3&4 PLANT MIXED ROWS OF THE FOLLOWING;
WESTERN AUSTRALIAN GOLDEN WATTLE (ACACIA SALIGNA)
ROCK SHEOAK (CASUARINA HUEGLIANA)
GUNGURRU (EUCALYPTUS CAESIA)

ROWS 5,6,7&8 PLANT MIXED ROWS OF THE FOLLOWING;
RIVER RED GUM (EUCALYPTUS CAMALDULENSIS)
YORK GUM (EUCALYPTUS LOXOPHLEBA)
WANDOO (EUCALYPTUS WANDOO)

control some of these areas. In spite of these precautions such areas may still blow.Crop yield are depressed over the poor sands and the best long term solution may be to fence the area off and plant it to deep rooted perennial fodder plants such as tagasaste.

In the short term the area should be stabilised using cereal rye or blue lupins.The following year direct seed to tagasaste or Western Australian Golden wattle.Tagasaste is a proven fodder plant while golden wattle has not been widely tested and is still the subject of some speculation. The tagasaste should be spaced about 1 m apart in rows 5 m apart. The wattles should be planted 2 m apart in rows 5 m apart. The tagasaste should be inoculated if grown from seed. Planting large areas using tagasaste seedlings will be costly.

In subsequent years weed control will be necessary as wild turnip and radish will volunteer. Tagasaste requires careful grazing and north and south topping to make it available to sheep. The planting of rows should always be across the direction of the most destructive winds.

Management of shallow soils with a rock substrate

Some areas in this district have thin hard setting soils, underlain at shallow depth by metamorphosed granites in some case, and by indurated laterites in others.
These areas grow little pasture and poor crops. In the long term these areas would be better fenced off and planted to shallow rooted trees such as York gum or wattles.

Tree planting priorities

Trees should be planted, in response to a problem on non productive areas. Before planting the trees the area should be fenced.If it is an area suitable for grazing, double fencing of the trees may be necessary. Prior to planting protection by banks and drainage will give the trees a better chance.

Trees should only be planted on productive stable areas if there is a specific reason, e.g. shade and shelter.

Banks and drains

The use of contour banks, or grade banks to control water or erosion should be a positive act, the area should be carefully surveyed and the banks constructed to adequate specifications.

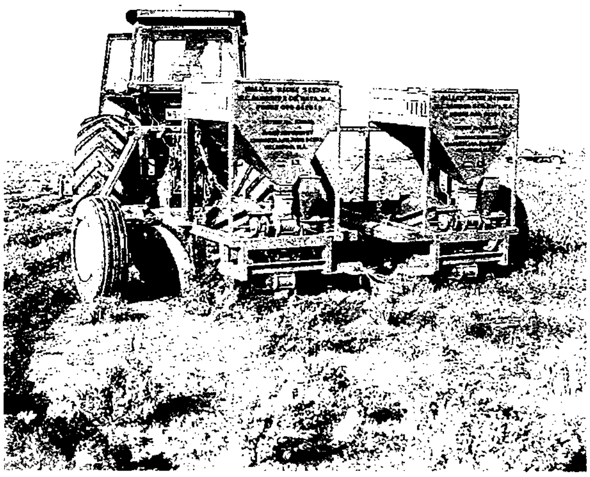
Contour banks should be spaced not more than 200 m apart, have a water channel cross section of 2.4 m2 and a settled height of not less than 0.9m.

They should be constructed from impermeable material, in sandy country they should be sealed using subsoil clay. Grade banks and broad based banks can have a settled height of between 0.6 m and 0.7 m but must discharge into a stable drainage line or fenced waterway. Photo No. 15 shows seeding on a broad based bank.

Although most banks will occasionally require maintanence, good quality banks will not fail at a critical time and will require much less maintanence. Specific structures such as gap spreader banks, spread water out of the depressions and direct it onto the interfluvial and drier parts of the paddock, thus making better use of the available rainfall. They require more detailed surveying and construction.

The Department of Agriculture has this expertise available.

When planning your banks, consider not only your own problem, but also the situation of farmers below you in the catchment, water not yet causing you a problem, could develop enough volume and velocity to cause problems just inside you neighbour's fence.



14. Seeding saltbush seeds using the Mallen seeder.

15. Seeding a broad based bank each run of the combine covers one facet of the bank.

Drainage

It is safe to say that most salt land or waterlogged areas will benefit from drainage. Drainage should not be carried out until investigations have shown that it is likely to succeed. Obviously the control of runoff from the paddock should be achieved to make the drainage more effective.

Where waterlogging occurs in paddocks with shallow soils over clay, banks can be used to intercept the water and take it safely to a drainage line or disposal area. An interceptor or reverse interceptor bank can be used.

Drainage can only be used where there is a safe and acceptable outflow area. Where the main problem is the disposal of surface water, a surface drain, less than 1 m deep will be more economical than a deep drain, 1 - 2 m deep.

Where permeable strata can be demonstrated, the deep drain will help to overcome a high water table problem. Tube drainage is a more expensive option and may be disposed to problems with plant roots or iron deposition blocking the tubes. It has a valuable role in collecting soakage water to produce farm water supplies, in lateral drainage where deep drains are used and to protect a valuable asset such as the homestead.

General comments

The dream of a decade ago, that some simple engineering solution would be found to overcome problems of soil degradation has vanished. The practical reality is that planned land use, careful management of crops, pastures and livestock and the use of trees will succeed in the long term.

5. CATCHMENT PLAN

Land Management Plan

Central to approaching the soil conservation districts' problems is the land management plan. This plan considers productivity along with soil conservation. Soil types are marked on your plan to enable you to see them as land production units.

This way you can look at land use in aspect of its long term effect on the soil, its productivity, optimum fertilizer application and crop rotations.

Farming in terms of soil conservation and landuse is more easily managed if the fences are located along soil boundaries, contour lines or natural barriers such as creek lines, farm tracks, ridges and saltland.

It is important to site sheds on well drained and stable sites. Land management planning is the concept of developing farm systems to allow your farm to evolve into a profitable and sustainable unit. Before every farming operation, whether planning for seeding or locating a new fence line, consider the long term effects of what you are about to do. The plan must be flexible and progressive, therefore what is planned today is a guide and can be altered with changing needs in the future. Each decision requires input from involved persons, family, partners and in some cases neighbours and the wider community.

The plan has been prepared considering your farm as an integral part of a soil conservation district. The intention is to help coordinate your farming activities along with the other members of the soil conservation district and so meet the districts problems more effectively.

Catchment data

Area of catchment	50,000 ha
Farmers involved	29
Area affected by salinity and waterlogging	6,500 ha
Area of severe salt and lakes	1,000 ha
Area of yellow sand and lightland	17,000 ha

About 10,000 ha of the Land Conservation District has adequate water control on the slopes. 15 000 ha is poorly controlled with few contour banks, or with poorly constructed banks. More banks are needed, a change to direct drilling practice where possible is a first priority. Some of the hard setting heavy soils would benefit from the use of gypsum, but only where the soil structure is severely degraded.

5.1 Stage 1

Complete contouring of the upper slopes and runoff areas. It is extremely important that the banks meet the required dimensions otherwise they will fail.

It is necessary that the planning and construction of the banks be done before any drainage is attempted. This is in order to protect the rights of the farmer on the lower end of the catchment. Time frame 1990 to 1991 (two years).

5.2 Stage 2

Fence off and plant trees below rocky catchments and on the fringes of saltland and windblow areas. These projects should proceed with urgency and need not wait until the contouring is finished. Whether you accept the double fencing recommendation depends on whether you wish to continue to graze the samphire areas whilst the trees on the fringes are growing large enough to survive grazing. Time frame 1990-1992 (three years).

5.3 Stage 3

Construct the main drain, at the same time the Shire will need to upgrade the culverts and road crossings. Time frame 1993-1994 (two years).

5.4 Stage 4

Individual farmers complete their own drainage systems, where required to feed into the main drain. Time frame 1994-1996 (three years).

5.5 Summary of Works Required

Construct 254 km of fence for saltland, drains, waterways and rocky areas.
Plant 166,000 trees.
Construct 27 km of fence or wind erosion areas.
Construct 206 km of level banks.
Construct 40 km of broad based or alternatively grade banks.

6. SUPPLEMENTARY REPORTS

6.1

EAST BALLIDU LAND CONSERVATION DISTRICT AGRONOMIC RECOMMENDATIONS & ECONOMIC SUMMARY

Analysed by: David Kessell, Department of Agriculture Moora
Written by: C.W. Thorn, Officer in Charge
Department of Agriculture Moora

Introduction

As a follow-up to the work of L. Lenane and C. Henschke, an evaluation of the economics of recommended land use changes was carried out.

This evaluation includes the detailed study of two farms within the Land Conservation District looking at the costs and returns from implementing the recommendations made. The data collected has also been used to adapt the North-Central Eastern wheatbelt (NCE) version of the MIDAS whole-farm computer model to the East Ballidu catchment area.

This report includes a summary of the information obtained from the farms studied, the optimum rotations and alternatives as selected by the NCE model and agronomic recommendations based on the NCE results and water use information.

A report on the predicted long-term ramification, both on a catchment basis and selected individual farm basis will be completed late in 1989 or early 1990 depending on the development of a new computer assessment model to look at changes over the long term.

Land use methods

The main aims of land use are to:

1. Increase or sustain profitability.
2. Prevent soil loss (wind/water erosion).
3. Prevent salinity and waterlogging by reducing ground water recharge by increasing water use on sandy soil types with high recharge.

Management methods

A number of management methods are available to achieve the above aims. These are:

1. Agronomic manipulation:
    a) This involves the use of lupin/wheat rotations on sandy soils to increase water use and reduce recharge (Figure 1).
    b) Increased fertilizer use to maximize growth and water use.
    c) Direct drilling (1 working and seeding) to reduce run off.
2. Tree planting on seeps to reduce waterlogging and reduce recharge.
3. Saltbush planting on saline soils to increase stock carrying in autumn, reduce recharge, reduce waterlogging.
4. Contour banks/working on the contour. This will reduce runoff and waterlogging increasing both crop and pasture yields.
5. Fence off saline/wind eroded areas to control stock grazing, allow regeneration.

Land Management Units	Optimum rotation	Fertilizer Wheat	Lupins
Earthy sands	WWL	45-50 kg/ha DAP +40 kg urea (seeding)	100 kg/ha super
Lateritic podzolic Red Earth	WWL PW (medics)	As above 35-40 kg/ha DAP +40 urea	
Grey Clay	WWWW WWWF WPWP (medics)	30-35 kg/ha DAP +40 kg/ha urea (seeding) (gypsum application)	
Wind Eroded Earthy Sand	Revegetate	Tagasaste Cereal rye	
Saline areas	Revegetate	Saltbush Tall wheat grass	

Best Bet Options for Land Management Units

Earthy sand and lateritic podzolics

1. Lupin/ wheat/wheat rotations, with lupins sown before the break (dry sowing).
2 Limited grazing over summer to reduce erosion.
3 Use Phomopsis resistant lupins (Yorrel/Gungurru) with Yorrel on the heavier textured soils.
4. Sow wheat early if season is early - variety (Spear/Dagger before end of May or as early as possible).
5. Fertilizer: DAP plus urea for wheat, plain super for lupins.
6. Minimum tillage cereals (1 working and a seeding).
7. Sow in lupins into cereal stubble.
8 Weed control
   - Cereals
     - Glean/Logran pre-emergence
     - Hoegrass
     - Diuron/MCPA, Diuron/2,4 Amine
   - Lupins
     - Simazine (not Atrazine on sandy soils)
     - Brodal.

Red earth/grey clays

1. Pasture/wheat rotations using medics (barrel medic - Parabinga, burr medic - Serena).
2. Continuous wheat and wheat/pasture rotations.
3. Wheat/wheat/wheat/field peas rotations may also be useful.
4. Sow wheat early using Spear and Dagger before the end of May.
5. Use minimum tillage to sow wheat (1 working/seeding).
6 Sow medics (10 kg/ha) with 90 kg/ha superphosphate if necessary.
7 Let medics set a large seed bank in first year.
8 Only adopt field peas if you have developed the techniques for growing them.
9 Gypsum may be useful on the hardsetting grey clays to improve water infiltration and soil structure.

Salt affected area

Sow bluebush/saltbush. Using stocking rates of 40-50 DSE/ha bluebush can provide 1200-1500 grazing days/ha. Using the MIDAS model for Penenjori showed that salt affected land costs $40/ha in lost production. Growing bluebush can increase annual farm profits by $35/ha.

Saltbush can reduce grain feeding, increase sheep number carried, and result in cropping less wheat.

On farms with a large proportion of heavy land and considerable salt affected area it is profitable to have more winter pasture on heavy land and less wheat.

Wind eroded areas

The value of Tagasaste on wind eroded soils has been estimated at increasing the profit/ha to around $25.45/ha/

With both saltbush and Tagasaste, costs are high initially, but must be viewed as a longer term investment.

Analysis of a Farm in the East Ballidu Catchment

Climatic conditions

The climate of the study area is typically Mediterranean, with cold wet winters and hot dry summers. The total yearly rainfall has ranged from 230 mm-434 mm for the period 1983-87. The growing season rainfall (May to October) ranged from 148-293 mm (Table 1).

Table 1. Seasonal rainfall (mm)

Rainfall	J	F	M	A	M	J	J	A	S	O	N	D	Total
1983	2	1	36	11	14	115	61	55	37	11	50	41	434
1984	0	6	77	68	134	19	43	29	30	3	18	6	432
1985	16	15	29	3	49	32	70	60	31	20	13	9	348
1986	24	64	11	14	41	88	51	40	8	21	9	0	382
1987	0	0	5	25	27	30	41	31	6	12	17	36	230

Physical characteristics

		%
Soil units	Earthy sands	27.8
	Lateritic podzolic	43.1
	Red earth	8.5
	Grey clay	10.3
	Salt affected	8.1
	Other	2.2
		100%

Cropping History

In the last five years the major change in cropping on the farm has been the increased use of lupins in the last three years (Table 2). This has generally been at the expense of the area of pasture.

Table 2. Crop area as % of total farm area

	1983	1984	1985	1986	1987
Wheat	39.0	39.0	49.7	49.7	55.4
Lupin	6.0	10.2	13.8	20.7	30.5
Barley	3.7	3.5	3.0	-	-
Total crop	48.7	52.7	66.5	70.4	86.2
Pasture	51.3	47.3	33.5	29.6	13.8

Table 3. Average crop yield (kg/ha)

	1983	1984	1985	1986	1987
Wheat	1175	1241	1649	1498	1132
Lupins	1203	1373	1289	1234	552
Barley	1350	1376	1635		

Effect of rotations on crop yields

The effect of agronomic rotations on wheat and lupin yields is shown below. In general wheat yields following pasture were increased by around 100 kg/ha for each year of a pasture ley (i.e. wheat following three years of pasture is around 300 kg/ha higher yielding than wheat following one year of pasture)(Table 4).
Continuous cereal cropping decreased wheat yields by around 100 kg/ha for each successive crop year.

Wheat yields following lupins in a lupin/wheat rotation was equivalent to wheat following one year of pasture, while the yield of the second wheat crop in a two wheat/lupin rotation was 100 kg/ha lower yielding than wheat after lupins.
Lupin yields were similar whether in a wheat/lupin, WWL or WWWL rotation.

Table 4. Yields (kg/ha) of wheat and lupins in rotations

	Yield kg/ha
Wheat following pasture	
1 year pasture	1350
2 years pasture	1428
3 years pasture	1619
Wheat following wheat	
1st wheat	1422
2nd wheat	1310
3rd wheat	1559
4th wheat	1280
5th wheat	851
Wheat following lupins	
After lupins	1345
After lupins/wheat	1245
Lupin yields	
L/W rotation	948
LWW rotation	730
LWWW rotation	905

Current rotations

The major rotation practices are lupin/wheat, pasture/wheat and two pasture/wheat.

Rotation	% of total area cropped
LW	27
PW	18
PPW	15
PPPW	10
WWL	10
PPPWW	8
PWW	4

Rotation practices on each soil type

Table 5. Rotations practiced in decreasing order of importance

Earthy sands	Lateritic podzolic	Red earth	Grey clay
LW	PW	PPW	PPWW
PPWLW	PPWW	PPPW	WWP
WLWWL	PPPW	WWWPP	WPP
PWPWL	PWLW	WWWW	
WPPP	PWW	WWP	

Table 6. Crop yield by soil type

	Yield (kg/ha)	
	Wheat	Lupins
Earthy sand	1325	1078
Lateritic podzolic	1403	1256
Red earth	1664	-
Earthy sand/lateritic mix	1260	841
Red earth/lateritic podzolic	1176	993
Grey clay	1360	-
All soil types mixed	1193	470

The lateritic podzolic soils and earthy sand soils gave the highest lupin yields, while red earths gave the highest cereal yield.

Summary of information from farm studies

Physical	Farm A	Farm B
Soil units (%)		
ES/WE (Earthy sands/wind erodible)	2.7	
ES (Earthy sands)	27.8	23.1
LP (Lateritic podzolics)	43.1	33.2
GBP (Grey brown)	7.4	
RE (Red earths)	8.5	12.5
GC (Grey clay)	10.3	
RK (Red calcareous)		1.8
Salt affected	8.1	19.3
Other	2.2	
Cropping		
% farm in crop (1989)	86.2	79.3
Wheat	55.4	57.8
Lupins	30.8	21.5
Pasture	13.8	20.7
Yields Wheat	1.36	1.23
(t/ha) Lupins	0.96	1.07
Yield efficiency (kg/mm annual rainfall)		
Wheat	3.83	
Lupins	3.06	
(kg/mm May-October rainfall)		
Wheat	5.71	
Lupins	4.57	
Sheep Stocking rate av (DSE)	4.0	6.0
Wool cut av (kg)	4.1	3.1
Ewes %	45.0	53.5

Whole farm model (MIDAS)

An updated version of the MIDAS (Model of an Integrated Dryland Agricultural System) for the Ballidu area was run based on actual data from farmers in the survey.

The model calculates the optimum rotation for each soil type to give maximum net profit. The model is based on a farm size of 1350 ha.

Table 7. Results of Midas runs (wool at $5/kg greasy, wheat at $140/tonne)

	NCEPercentage crop runs									
Crop%	10	20	30	40	50	60	70	80	90	100
Net profit	30395	45523	54703	60122	66400	73224	78691	82337	8516	84396
Crop area (ha)	135	270	405	540	675	810	945	1080	1215	1350
No. of sheep	4949	4439	4948	3416	3049	2276	1646	1259	673	0
Peak debt	19179	30258	37746	44175	46666	52341	57685	61903	70517	93309
Stocking rate	1.4	4.1	4.3	4.2	4.5	4.2	4.1	4.7	5.0	0.0
Grain feeding (tonnes)	97	73	71	69	55	39	27	21	11	

Table 7 (continued)

	Optimum rotations at each % cropping									
	10	20	30	40	50	60	70	80	90	100
S1	PPPP	PPPP	PPPP	PPPW	PPPP	PPPP	PPPP	WWL	WWL	WWL
S2	PPPP	PPPP PPPW	PPPW	PPPW	WWL	WWL	WWL	WWL	WWL	WWL
S3	PPPP	PPPP	PPPP	PPPW	PPPW	PPPW	PPPW	PPPW	WWL	WWL
S4	PPPP PPPW	PPPW	PPPW PPW	PPW PWPW	PPW	PPW WWL	WWL	WWL	WWL	WWL
S5	PPPP	PPPW	PWPW	PWPW	PPPW PWPW	PWPW	PWPW	PWPW	PWPW	WWWF
S6	PWW	PWW	PWW	PWW	PWW	PWW	PWW	WWWF	WWWF	WWWF

P = pasture; W = crop; F = field peas; L = Lupins.

The Effect of % of Farm in Crop on Profit

The model selected that the optimum net profit was when between 80-90% of the farm is in crop.

The two farmers in the study had a cropping percentage at near the optimum selected by the model. This is not average for the district, which is around 50-60% cropping. As the percentage of cropping on the farm increases, lupins replace pasture.

At the average farm cropping percentage of 60%, the rotations selected on each soil type compared to 90% are described below.

	60% cropping	90% cropping
Earthy sand	WWL	WWL
Lateritic podzolic	PPC, WWL	WWL, WLWPP
Red earth	PW	PW
Grey clay	PWW	WWW,WWF

Lupins replace pasture on the lateritic podzolic (sandy gravels) at the higher % cropping. This is only applicable when the depth of topsoil is at least 0.5 - 1.0m deep.

The model selected an average stocking rate of 4.7-5.0 sheep/ha. The two case study properties were stocked at 4-6 sheep/ha.

Around 11-21 tonnes of grain feeding was found in the model.

The net return was optimised at $85,160 or $63/ha.

Rotations selected for each soil type

The rotations selected for each soil type are listed below. The figures in brackets are the value ($/ha) that the next closest rotation is to the optimum solution.

A. Earthy sand (S2)

Model			Farmer rotations
WWL	(BB)		
WWL	(OB)	(3.20)	
WL	(BB)	(18.00)	WLW
WL	(OB)	(23.00)	
PPLW		(18.00)	PPWL

(BB) sown before the break; (OB) sown after the break.

The model suggests that a two wheat/lupin rotation with the lupins sown before the break, although lupins sown on the break is very close ($3.20/ha) from the optimum solution.

The suggestions from the model are:

1. That two wheat/lupin rotations are more profitable than the lupin/wheat rota tion. This rotation has the advantage of decreasing lupin root and leaf disease problems in lupin/wheat rotations.
2. This soil type is the primary soil type for lupin cereal rotations.
3. Pastures are not an option on these soils.
4. Lupin should be sown early - this means weeds have to be controlled in the cereal crops (i.e. radish, capeweed).

B Lateritic podzolics (sandy gravels) (S4)

	Model			Farmer rotations
1	WWL	(BB)		1 PW
2	WLWPPP		(2.34)	2 PPW
3	WWL	(OB)	(3.20)	3 PPPW
4	WF		(6.05)	4 PWLW
5	PW		(19.50)	
6	PPW		(14.60)	
7	PPPW		(18.70)	
8	WL	(OB)	(38.00)	

The model selected the two wheat/lupin rotation sown before the break (dry) as the best rotation. The sowing of lupins on the break is a second option. The third best option is WLWPPP rotation, however this rotation requires resowing pasture.

The farmer practice on this soil is a pasture/wheat rotation either in a short ley or a three year pasture ley. These rotations are ($14.60-19.50/ha) away from the optimum rotation.

Farmers in the catchment may consider this soil for lupin/wheat rotations. The only limitations is the depth of top soil. Lupins should only be grown where there is at least 1 m of top soil over the gravel bedrock Yorrel is the preferred variety on heavier textured soils.

C Red earths (S5)

	Model		Farmer rotations
1	WP		1 WWWPP
2	WWWF		2 WWPP
3.	PPWW	(1.67)	3 PPPN
4	WWWW	(2.63)	4 WWWW
5	PWW	(3.38)	

In general the farmers are practicing the optimum solutions of combinations of pasture/ wheat ley farming.

The agronomic options of this soil type is to sow medics (barrel medic Parabinga, burr medic Serena). These species are suited to short pasture/wheat rotations. A greater adoption of these new pastures is a recommendation.

D Grey clays (S6)

	Model		Farmer rotations
1	WWWF		PPWW
2	WWWW	(4.70)	PPW
3	WP	(10.90)	PWW
4	PPPW	(16.20)	
5	PPW	(12.90)	
6	PPWW	(15.50)	

The model has selected a high degree of cropping on the grey clays. Although these soils are productive they are generally low lying and subject to waterlogging and difficult to work.

The model suggests continuous wheat or three wheat/field peas as the optimum rotations.If more of the farm is in lupin/wheat rotations then these soil types may need to be in PWPW, PPW, PPPW rotations to maintain the area of pasture on the farm.

Pasture options are burr medic (Serena) and Parabinga barrel medic.

Summary of NCE MIDAS Results
The updated version of the NCE MIDAS model gave the following selection of rotations:

Soil unit	Area (ha)	Selected rotations	
1	75 (100%)	W W L(Bef)	
		W W L(On)	($3.20)
2	300 (100%)	W W L(Bef)	
		W W L(On)	($3.20)
3	225 (100%)	W W L(Bef)	
		W L W P P P	($2.34)
		W W L(On)	($3.20)
		W F	($6.05)
4	300 (100%)	W W L(Bef)	
		W W L(On)	($3.20)
5	13 (5%)	W P W P	
	287 (95%)	W W W F	
		P P W W	($1.67)
		W W W W	($2.63)
		P W W	($3.38)
		W W L(On)	($6.85)
		P P W	($8.43)
		W W L(Bef)	($9.47)
6	150 (100%)	W W W F	
		W W W W	($4.77)

W = wheat L = lupins P = pasture F = field peas

Soil Type		Description	pH range
Poor light	(S 1)	Deep infertile sands	5.2-5.6
		or Acid sands (wodgil)	@ 5.2
Good light	(S 2)	Yellow loamy sand with gravel at F 1 m	5.5-5.9
Sandy gravel	(S 3)	Shallow sand or gravel over massive laterite	5.5-6.0
Duplex	(S 4)	Grey sand or loamy sand with increasing gravel at depth	5.5-6.0
Good loam	(S 5)	Red/brown sandy clay loams over clay	6.0-7.0
Valley clay	(S 6)	Grey clay/alkaline red clays	@ 7.0

Conclusion

Further development of this work is needed to:

1. Run YI YO budgets for the implementation of the farm plan (i.e. least cost option, maximize return). This will be conducted in the future (November 1989) as part of an evaluation of the F.A.R.M.S. programme.
2. Do further runs on the MIDAS model to evaluate the returns from saltbush and tagasaste at Ballidu.
3. Deep ripping has applicatibility to the earthy sand soils and further economic evaluation of deep ripping is warranted.

SURVEY OF LANDHOLDER ATTITUDES TO LAND CONSERVATION IN THE EAST BALLIDU LAND CONSERVATION DISTRICT

Survey by: East Ballidu Land Conservation District
Written by: C.W. Thorn, Officer in Charge, Moora District Office
Department of Agriculture

Introduction

A survey of landholder attitudes to the:

1. East Ballidu Catchment Plan;
2. individual farm plans;
3. implementation of farm plans;
   (a) economic constraints;
   (b) measures to adopt;
   (c) priority order for works to be implemented;
4. future direction of the group;
5. future level of support from government agencies;

was conducted following the release of the Draft Catchment Report.

The survey consisted of 24 questions aimed at answering the above questions. The survey was conducted with 29 landholders in the catchment. There was 65% response to the survey.

The survey form is attached at the end of the report.

The Draft Report

The first six questions dealt with landholders' attitudes to the draft report.

Attitudes to the Draft Report

Survey responses (Q1-6)

- Most landholders were happy with the content of the report, however, more detail was required. The details required were:
  - plans for the phased implementation of each individual plan;
  - more details on individual farm plans (e.g. location of seepage areas, remnant vegetation, more detailed soil type definition).
- The landholders found the report:
  - readable;
  - easy to follow;
  - value for money.

Attitudes to Recommendations in the Report

Survey response (Q7-17)

Questions 7-17 dealt with the recommendation in the report ranging from rotations, revegetation of degraded areas, fencing degraded areas and earth works.

- Most farmers felt that more time should have been allocated to the discussion of the draft farm plans to agree on the final farm plan.

- The recommendations focussed on four areas: drainage, fencing, plantings on degraded areas and runoff control. The survey indicatedthat the landholders' preference for im plementation of works was:

  1 Contour banks.
  2 Fence off degraded areas.
  3 Revegetate degraded areas.
  4 Deep drainage.

- The survey consensus was for work on the upper parts of the catchment to precede deep drainage.

  1 Contour banks.
  2 Dozer built banks.
  3 Deep drainage.

- In terms of fencing off degraded areas most landholders were willing to fence off degraded areas as long as it combined with other works.

- In terms of revegetating degraded areas, the order of preference for plantings were:

  1 Trees.
  2 Saltbush.
  3 Tagasaste.

- Landholders require more information on:

  1 Tree species, site selection.
  2 Economic value of saltbush.

- In terms of drainage, the landholders wish to adopt the recommendations of the report, but only when works are commenced higher up in the catchment. There is a require ment for the spur drains and an improved central drain.

- In terms of the landuse on soil types, most were happy with the recommendations in the report, however, many felt the MIDAS model selected too high a percentage of cropping (model selected 80% cropping, district average 60%).

Community Attitudes to Financing Conservation Works

Survey response (Q18, 21, 22)

- Landholders indicated a mixed reaction to contributing to works which would benefit the whole catchment. About 60% indicated they would contribute.

- Most landholders were prepared to allocate a percentage of the yearly budget to land conservation measures.

- Most landholders would not contribute to main drain unless other measures were in place (contouring, trees, refencing)

- Most landholders believed the future work by East Ballidu Land Conservation District (EBLCD) should be funded from Government grants.

Other aspects of the survey

- Landholders would like more on-farm agronomic advice to show how it fits in with conservation (e.g. tillage system, rotations, lupin soil type response, etc.).
- The EBLCD would like demonstration of electric fencing.
- The EBLCD would also like to see water controlled on reserves.
- The EBLCD would like to see an extension booklet on a guide to trees (species, soil type, use, value etc.).
- More draft reports were required than what was received.

SUMMARY

The catchment planning work at East Ballidu has provided valuable information on:

1 preparing plans;
2 agronomic manipulation of farm practices;
3 community attitudes to land conservation;
4 provided a focal point for the group.

The East Ballidu Land Conservation District concluded that the order for implementing the recommendations of the report is:

1 contouring, working on the contour;
2 fence off degraded areas;
3 revegetate degraded areas;
4 deep drainage.

6.2

HYDROLOGICAL INVESTIGATION - EAST BALLIDU CATCHMENT

C.J. Henschke, Department of Agriculture, Moora

6.2.1. Summary

To complement the production of an integrated catchment management plan for the East Ballidu Soil Conservation District, hydrogeological investigations were carried out at four sites within the catchment. These sites included:

(1) characterization of a saltbush demonstration site along the margin of a broad valley floor;
(2) monitoring the effect of flooding on shallow watertables within the broad valley floor;
(3) investigation of a suitable site for tree planting to reclaim saline seepage; and
(4) monitoring watertables in a tributary valley to provide an advanced warning system for salt encroachment.

Boreholes were drilled at each site and samples collected at 0.5 m intervals for laboratory analysis. Piezometers and observation wells were installed and monitored at fortnightly intervals. Continuous water level recorders and a tipping bucket raingauge were installed at one site. Soil inspection pits were excavated at two demonstration sites and the profiles were described, sampled and classified. Geophysical surveys (electromagnetic induction and magnetic) were also carried out at each site.

Results showed the existence of three separate groundwater systems in the landscape; a deep regional semi-confined system, an unconfined perched groundwater system occurring in deep sandplain and shallow seasonal perched watertables developing at the interface of the A/B or B/C horizons in the soil profile. Both the shallow and the deep groundwater systems in the main broad valley showed rapid responses to heavy winter rainfall events.

Strategic tree planting in the landscape is a recommended option for groundwater management. Within the broad valley floor trees should be planted in sandy-infilled palaeo drainage lines and around the periphery of severely salt affected land. A block of trees planted immediately upslope of sandplain seeps will help to intercept the flow of perched groundwater to the seep.

Drainage systems should be used for rapid removal of excess surface water accumulations in low-lying areas, before this water can recharge shallow and deep groundwater systems.

6.2.2. Introduction

The East Ballidu catchment has an area of 49,000 ha of which about 10 per cent is currently saline. Drainage within the broad central valley floor is ill-defined and consequently flooding and waterlogging problems occur.
Four demonstration sites were selected within the catchment for which a detailed description of soils and hydrology was required. The following table provides details of each site.

Table 1. Description of sites characterized in the East Ballidu catchment

Site	Identification Symbol	Description	AMG Reference	
1	S	Saltbush demonstration	491300	6617000
2	F	Flooding of paddock	491600	6616300
3	T	Tree planting on seep	481400	6624200
4	W	Watertable monitoring	489600	66137000

6.2.2.1 Saltbush demonstration site

There are large variations in success for establishment of salt tolerant plants especially using direct seeding methods of establishment. This is thought to be associated with site/soil characteristics. Therefore site characterization is important for the future prediction of successful sites. As more sites become characterized, this will enable positive criteria for successful revegetation of saltland.

A 10 ha site was selected for a demonstration planting of halophytes on the fringes of a broad saline valley floor. The objective was to characterize the soils and hydrology at this site.

6.2.2.2 Flooding site

In many broad wheatbelt valleys, salinity has not reached a potentially severe stage because the topsoil is still intact and has plant cover growing on it. In this situation flooding and waterlogging can become a major factor in lost productivity because:

(1) Flooding limits plant growth which means the ground becomes bare and therefore vulnerable to water erosion. Loss of topsoil exposes the more saline subsoil clays resulting in salt scalds that are very difficult to rehabilitate.
(2) Flooding may also be a major contributor to high watertables. The concept of valley floors acting as recharge areas was discussed by McFarlane et al., (1988).
(3) Combinations of salinity and waterlogging have been shown to have a more significantly deleterious effect on plant growth than either salinity on its own or waterlogging on its own (Barrett-Lennard, 1986).

The objective at this site was to measure the effect of episodic flooding events on watertables. The broad central valley floor of the East Ballidu catchment has poor natural drainage and hence large areas have the potential to become inundated following heavy rainfall events.

6.2.2.3. Trees on seep site

Sandplain seeps are relatively common in the NE wheatbelt. They are typically 1-10 ha in size and are caused by a relatively fresh perched groundwater system seeping out at the interface of aeolian sands and underlying clays.

Deep yellow sands upslope of the seep are significant recharge areas and most annual crop and pasture species are incapable of using all of the seasonal rainfall before it percolates down past the root zone. A local perched watertable develops on sandplain hardpan ("silcrete") and may also contribute recharge to the deeper regional groundwater system. Interception of the perched watertable may be achieved using a contour belt of trees planted upslope of the seep. In this situation the tree roots will have access to a relatively shallow and fresh watertable. For most seeps, between 100 and 1,000 trees should effectively de-water the perched system by the time the trees are 3-5 years old (R.J. George, pers. comm., 1988).

The objective at this site was to demonstrate the effectiveness of trees in the reclamation of a sandplain seep.

6.2.2.4 Watertable monitoring site

From monitoring the trends of groundwater in valleys which are not yet saline, it should be possible to provide an advanced warning system for salt encroachment.

The objective at this site was to strategically place a number of monitoring bores in a tributary valley where salt was encroaching back up the valley. Landholders should continue to keep a regular check on water levels so that preventative measures can then be undertaken if waterlevels begin to rise.

6.2.3. Methods

6.2.3.1 Deep drilling and groundwater measurements

Boreholes were drilled at each of the four sites during April 1988. A power rotary auger drill-rig was deployed for the drilling operation. Watertable observation wells were drilled to an average depth of 2.1 m. The open holes were lined with fully slotted 40 mm diameter PVC tubing and backfilled with sand.

Piezometers were installed in holes drilled to depths of 7 m or greater, by inserting 40 mm PVC tubing slotted over the bottom two metres. Sand was poured down the annulus to completely cover the slotted section followed by a bentonite clay slurry to form a watertight seal. After backfilling the hole with sand a protective clay pipe was sealed into a cement grout at the soil surface.

During drilling, at least one of the deep bores at each site was sampled at 0.5 m intervals down the hole. The soil samples were analysed in the laboratory for gravel percentage, pH, electrical conductivity (EC) and chloride ion concentration (Cl^-). Chemical analyses were carried out on 1:5 soil-water extracts.

The relative elevations of the bores at each site were surveyed. Waterlevels were measured at fortnightly intervals and samples taken monthly for laboratory analysis of EC and Cl^-. At site 2, the two observation wells were instrumented with continuous automatic waterlevel recorders (AUSI) for recording short term fluctuations in waterlevels. A tipping bucket raingauge was sited adjacent to the wells to relate rainfall to change in waterlevel.

6.2.3.2 Soil profile description and measurements

Soil inspection pits were excavated with a backhoe at sites 1 and 3. The soil profiles were described and classified according to the principal profile form factual key of Northcote (1979). Soil horizons were sampled for laboratory analyses of pH, EC, Cl^-, saturation percentage, EC of saturation extract (EC_e), cation exchange capacity (CEC) and the exchangeable cations - Ca^{2+}, Mg^{2+}, K^+, Na^+.

6.2.3.3 Geophysics

Electromagnetic terrain conductivity measurements using a "Geonics" EM38 were carried out at each site. Electromagnetic induction is an efficient remote sensing technique which provides a rapid, repeatable and non-destructive method of measuring soil salinities. Readings were taken in both the horizontal and vertical modes. In the horizontal mode most of the instrument response is from the 0-0.3 m soil depth range, while in the vertical mode the response is from a greater depth interval (0-1.2m). A magnetic survey using a "Geometrics" proton precession magnetometer was carried out at site 4. Magnetometers are capable of discriminating between rocks of different magnetic mineral assemblies, and can be used for detecting basic dolerite dyke intrusions. Engel et al., (1987) has shown a relationship exists between the occurrence of dolerite dykes and soil salinity. Dolerite dykes can act as hydraulic barriers, impeding the flow of groundwater out of catchments and resulting in saline seeps.

Surveys were done on a grid basis with 20 m station spacings at each site. Traverse line spacings were 25 m apart at sites 1 and 3, and 50 m apart at site 2. A single traverse between piezometers was carried out at site 4.

6.2.3.4 Calculation of number of trees required above a sandplain seep

At site 3, the following parameters were used to calculate the number of trees required to intercept and dry up the perched watertable.

Area of catchment	=	200 ha
Area of deep yellow sand	=	100 ha
Area underlain by a perched watertable	=	30 ha
Average annual rainfall	=	320 mm
Average annual recharge	=	10 mm
Area of saline discharge	=	3 ha

Expected discharge (Q) over the 3 ha site is given by:

$$Q = \text{recharge} \times \text{catchment area}$$
$$= 10 \text{ mm y}^{-1} \times 30 \text{ ha}$$
$$= 0.01 \text{ m y}^{-1} \times 30 \times 10^4 \text{ m}^2$$
$$= 3{,}000 \text{ m}^3 \text{ y}^{-1}$$

Assume that the average water use (E_t) of trees after 5 years is 10 m^3 y^{-1}, then the number of trees, x, is given by:

$$x = Q/E_t$$
$$= 300 \text{ trees}$$

Approximately 400 trees were planted in a contour belt upslope of the seep on July 6, 1988. This will allow for natural wastage through tree deaths and thinning should probably be carried out after 5 years.

6.2.4. Results

6.2.4.1 Borehole logs

The drilling logs at each site are presented in Appendix 3. Profiles typically consisted of sandy topsoil over clay and/or lateritic gravel. A hardpan of sands and clays indurated by siliceous and ferruginous cementing agents occurred at various depths between 1.5 and 7.0 m below the ground surface. Below this there occurred a pallid zone consisting of soft pale coloured, clayey sands to sandy clays. Bedrock was encountered at 12.7 m at site T1, but was deeper than 17 m at all other sites.

Table 2. Profile chloride ion storage

Site	S1	S3	T1	W1
Cl^- storage (kg m^{-2})	13	28	17	55
Cl^- storage (tonnes ha^{-1})	130	283	169	545
Profile depth (m)	7.5	17.5	12.7	17.5

6.2.4.2 Groundwater monitoring.

6.2.4.2.1 Saltbush site

The shallow watertable only showed a difference in level of about 25 cm between the severely salt affected site (S1) and the mildly affected site (S3), during the monitoring period. However, the Cl^- concentration of the shallow groundwater at site S1 was more than double that at site S3. The watertable responded rapidly to the onset of winter rainfall.

The piezometric surface averaged 0.30 m below the ground surface at the severe site (S1) and 0.37 m below the surface at the mild site (S3). The piezometric surface also showed a rapid response to winter rainfall. Groundwater hydrographs indicated that there was good hydraulic connection between the top and lower sections of the groundwater flow system. Vertical hydraulic gradients were in an upwards direction at each of the three sites with the strongest uward heads occurring in autumn. At sites S2 and S3, very slight downwards head gradients (-0.03 m/m) occurred after heavy rainfall.

Drilling indicated that the confining layer for deep groundwater ranged from a thickness of 3 m at site S3 to over 6 m at site S1. The confining layer was composed of dense clay overlying indurated sands and clays. Pits excavated into this zone showed that it was a leaky bed with groundwater seeping upwards through macropores, voids and old tree root channels.

6.2.4.2.2 Flooding site

Figure 1 is a hydrograph showing watertable responses to rainfall events and is a graphical summary of information gained from the pluviograph and continuous water level recorder charts.

These data show that the pre-winter watertable was almost 2 m below the ground surface. During June, heavy rainfall resulted in flooding and waterlogging at this site. A shallow perched watertable (Cl^- = 3,180 mg/L) developed at the A/B horizon interface in sandy topsoil on top of clay. The regional watertable (Cl^- = 5,600 mg/L) rose rapidly and peaked at 0.5 m from the ground surface (the piezometric surface was not monitored at this site). The shallow perched watertable also peaked rapidly following winter rainfall events and then decayed steadily back to dryness. This pattern continued from May until October.

6.2.4.2.3 Trees on seep site

A hydrogeologic cross-section of the sandplain seep is shown in Figure 2. A local unconfined groundwater system (Cl^- = 130-200 mg/L) was perched on top of a "silcrete" hardpan (see Appendix 1). The thickness of the aquifer was 0.5 to 0.7 m. The salinity of this groundwater system rose sharply within the seep, reaching a maximum Cl^- content of 4,640 mg/L at site T1.

The deep regional groundwater flow system (Cl^- = 2,000 mg/L) had a saturated thickness of 11 m. The groundwater was confined by a 2.5 m thick hardpan within the seep area. Hydrographs (Figure 3) suggest poor hydraulic connection between shallow and deep groundwater because of dissimilarity of responses.

6.2.4.2.4 Watertable monitoring site

Site W1 was located at the saltland/freshland boundary in a tributary valley. The shallow watertable (Cl^- = 1,100 mg/L) responded rapidly to winter rainfall rising by 1.28 m between May and June (see Figure 4). The piezometric surface (Cl^- = 4,130 mg/L) was relatively static or rising slowly. The overall rise was 30 cm in 4 months. During autumn there was an upwards head gradient of +0.02 m/m. A gradient reversal occurred at the onset of winter rainfall with a downwards gradient (-0.04 m/m) during winter.

Sites W2 and W3 were located in two subdued valleys, 300 m upslope of W1. Profiles (see Appendix 1) consisted of loamy sands over shallow lateritic gravel. Heavy clay overlying hardpan occurred at depths of 2 to 6 m. The piezometric surface at both sites was 4-5 m below ground level, did not respond to winter rainfall events and showed a constant trend with time. During winter a shallow perched ephemeral watertable developed at 1.2-1.4 m depth in the lateritic gravel above the clay/hardpan layer.

6.2.4.3 Soil characterization

Soil profile descriptions for three sites within the saltbush trial site and for one site within the sandplain seep are given in Appendix 8. Chemical analyses of these soils are given in Appendix 9.

6.2.4.3.1 Saltbush site

The soil profile at the severely salt affected site (EB1) was classified as a yellow duplex soil (Dy 1.41). The characteristics of this soil are a distinct texture contrast between the sandy A horizon and the moderate to strongly pedal clayey B horizon.

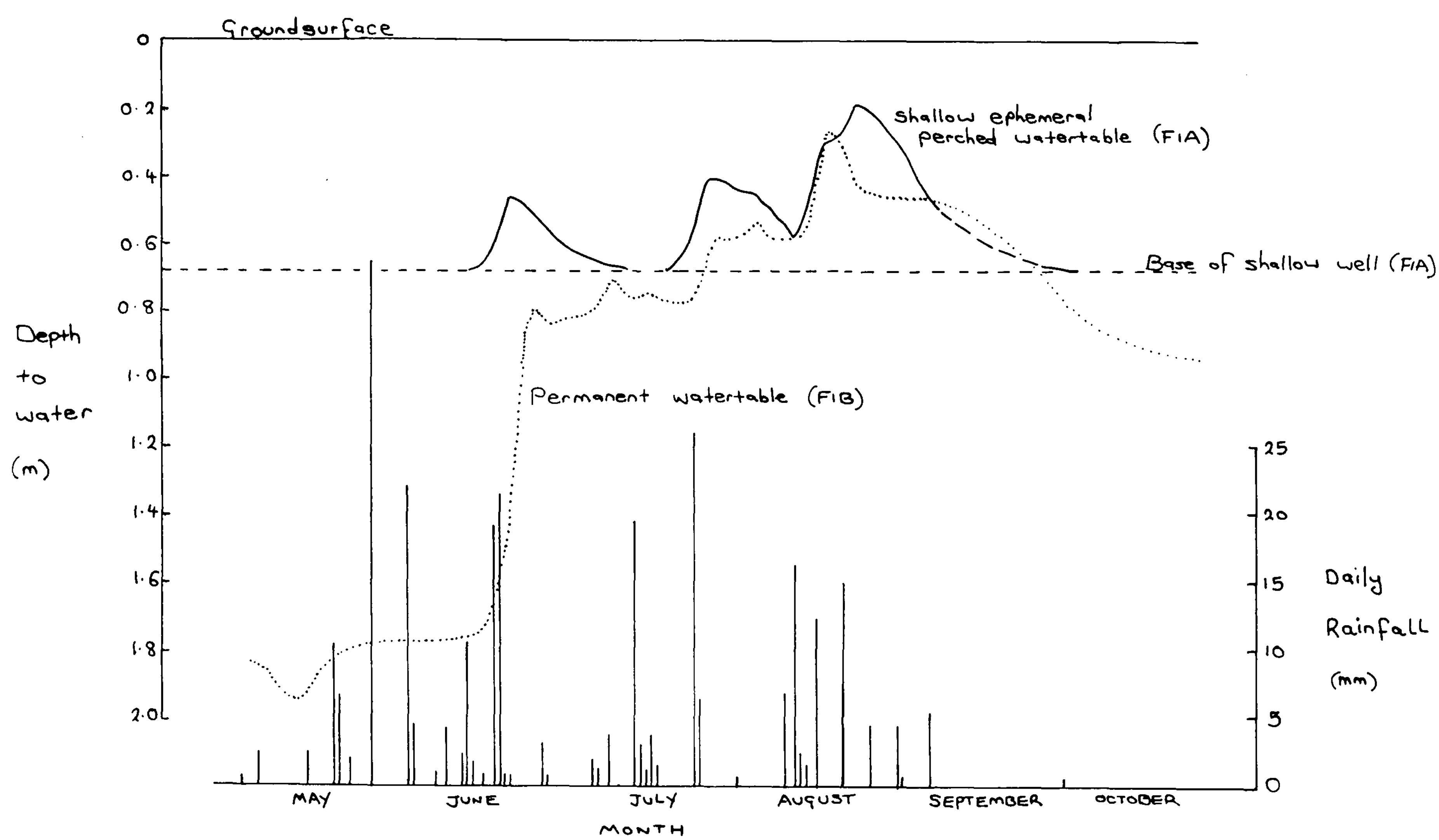


Figure 1 Hydrographs showing responses of permanent watertable (F1B) and shallow ephemeral perched watertable (F1A) to daily rainfall events during 1988.

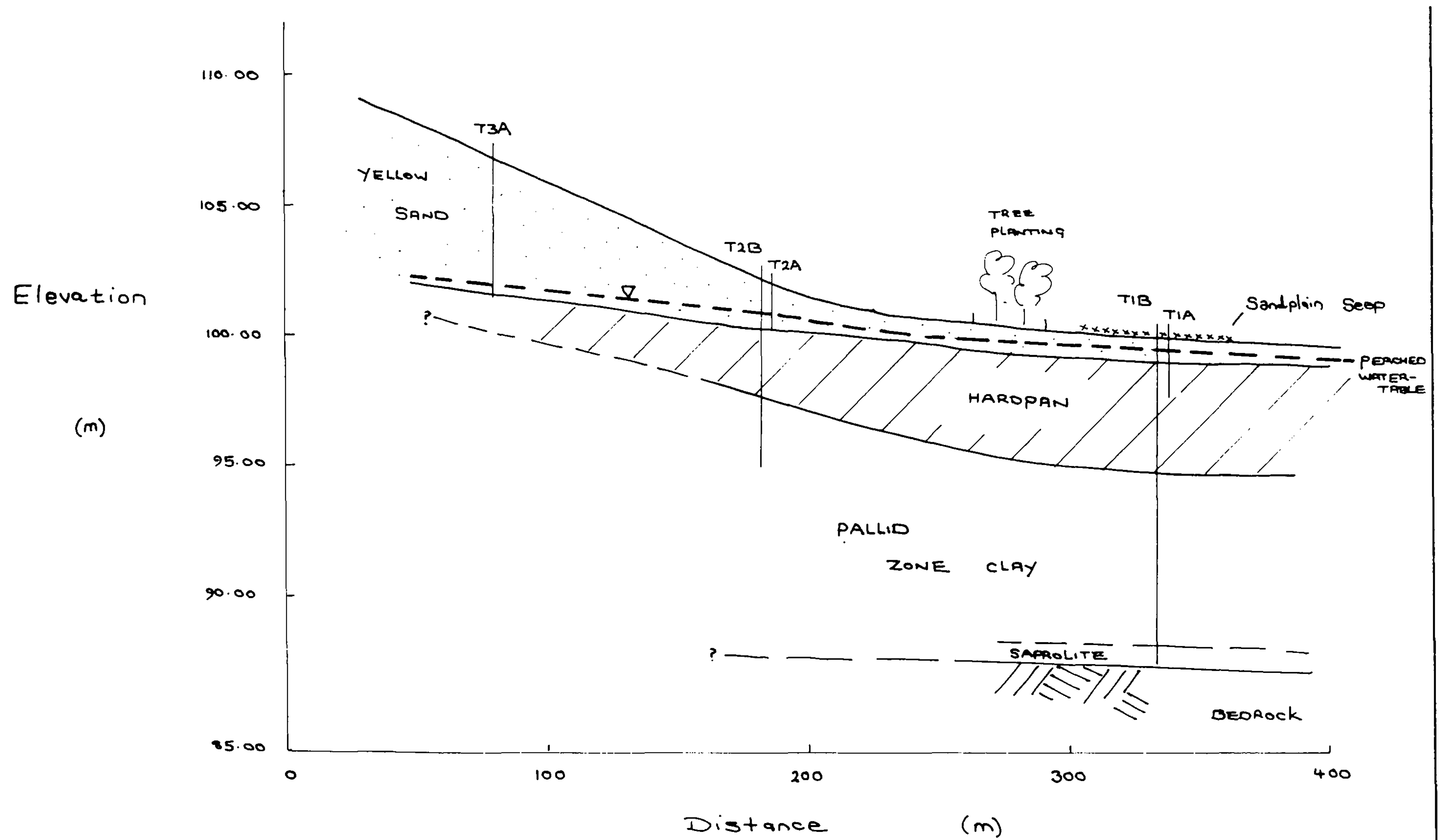


Figure 2 Hydrogeologic cross-section of sandplain seep

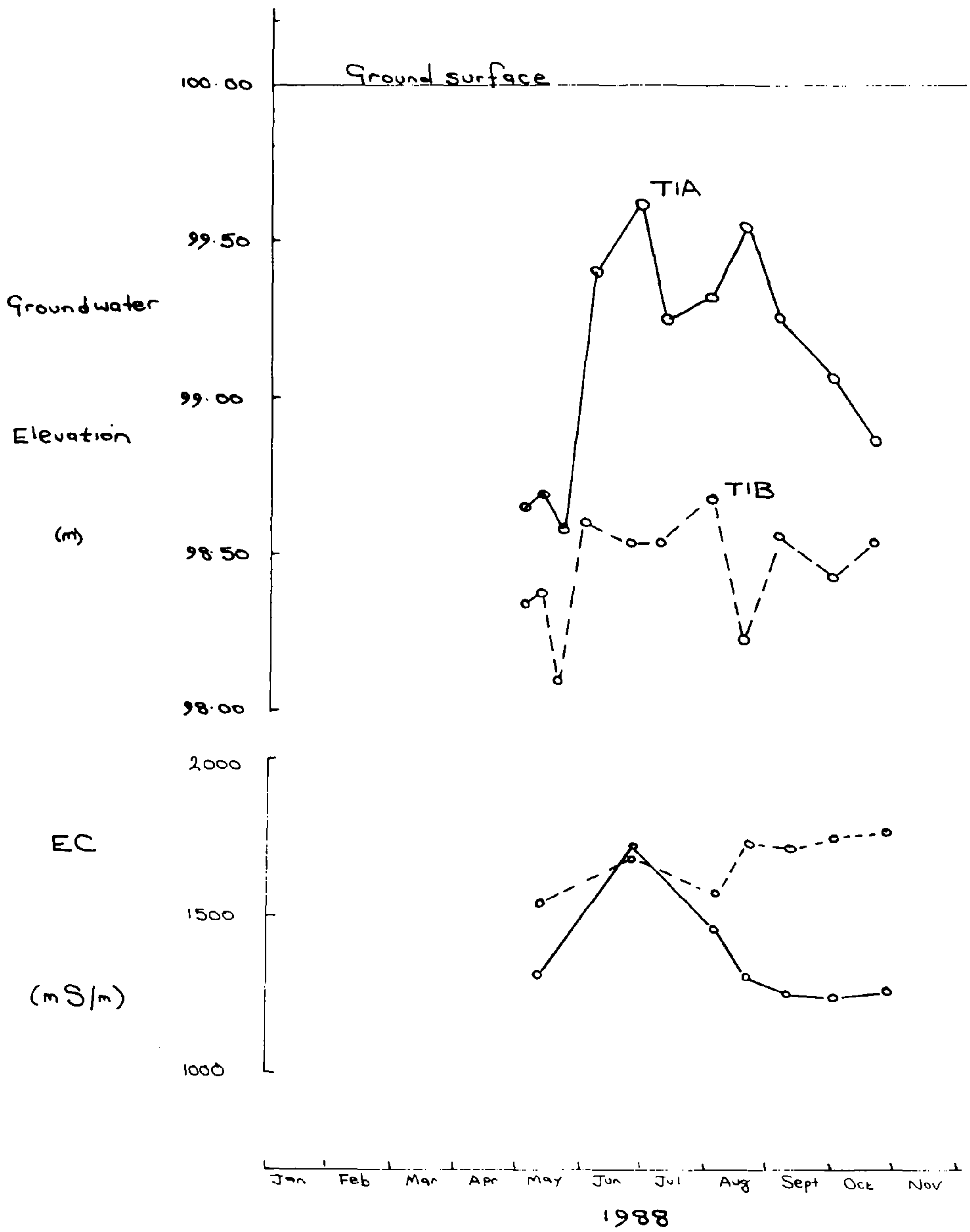


Figure 3 Hydrographs showing waterlevel and EC of groundwater at site T1, trees on seep site

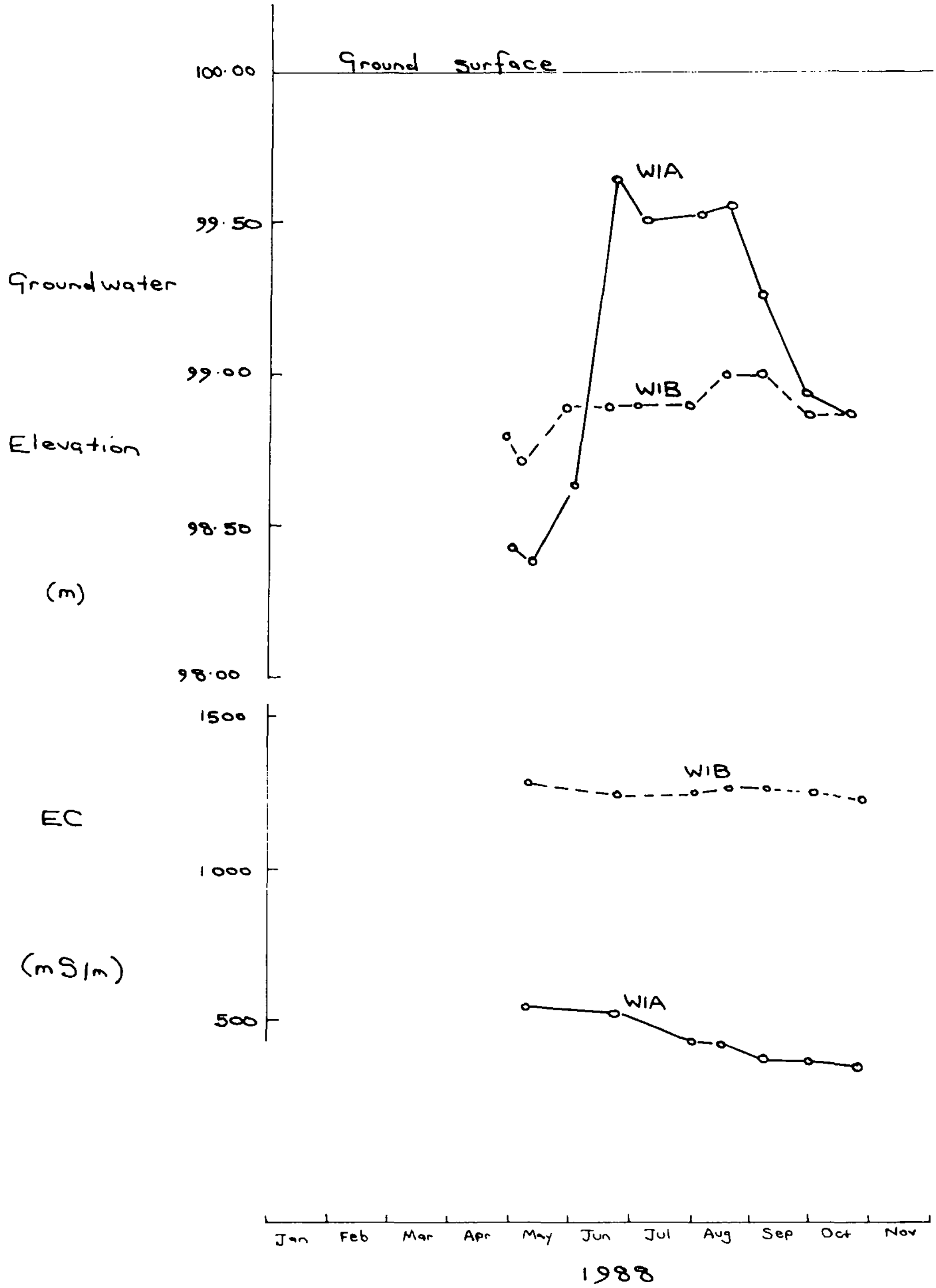


Figure 4 Hydrographs showing waterlevel and EC of groundwater at site W1, watertable monitoring site.

The A11 horizon had a thin surface crust, which was saline. A thin conspicuously bleached A2 horizon indicated periodic waterlogging. The B horizon was a mottled light yellow brown medium clay with a moderate to strong blocky structure. Subsoil clay had macropores which were transmitting saline groundwater under pressure

.

This profile showed an acid soil reaction trend (Appendix 5) with a surface pH of 5.8, dropping to 5.1 in the deep subsoil. The highest values of EC_e occurred in the top 10 cm (1,086 mS/m) and between 32-110 cm (1,100 mS/m). Since sampling was carried out during winter (June,14) it would be expected that topsoil salinity would be considerably higher during summer. Groundwater seeping into this pit (EB1) had an EC of 2,970 mS/m and a Cl^- content of 10,700 mg/L.

The soil profiles at the moderate (EB2) and mildly (EB3) salt affected sites were characterized by gradational texture profiles and hence classified as Gn 1.82 soils. The greyish brown sandy surface horizons graded to mottled pale yellow sandy clay loam B horizons. Ironstone gravels were overlying a laterite hardpan at around 60 cm depth. Macropores and old tree root channels were transmitting groundwater through the hardpan. At site EB2, the surface pH was 5.9, rising to 6.5 in the deep subsoil. The maximum EC_e (1,317 mS/m) occurred in the A11 horizon (0-14 cm). Groundwater seeping into pit EB2 had a EC of 1,860 mS/m and a Cl^- content of 6,160 mg/L.

At site EB3, the surface pH was 6.3, rising to 6.6 in the deep subsoil. The EC_e of the topsoil (0-10 cm) was 130 mS/m. The maximum EC_e in the profile was 250 mS/m at 57-80 cm depth. Groundwater seeping into pit EB3 had an EC of 1,110 mS/m and a Cl^- content of 3,620 mg/L.

6.2.4.3.2 Trees on seep site

The soil profile within the sandplain seep was classified as a bleached sand (Uc 2.12) on laterite. This is equivalent to a lateritic podzolic soil in the Great Soil Group nomenclature (Northcote et al., 1975).

This soil had a uniform coarse-textured profile and the conspicuously bleached A2 horizon was weakly mottled indicating leaching and seasonal waterlogging. The profile was underlain by ironstone gravel and a pisolitic laterite hardpan at 80 cm. Macropores and old tree root channels were transmitting groundwater through the hardpan.

The surface pH was 6.7 at the surface decreasing to 6.3 in the subsoil. The maximum EC_e (795 mS/m) occurred in the A1 horizon (0-4 cm) and EC_e decreased with depth to 56 mS/m in the subsoil (20-50 cm).

6.2.4.4 Geophysics

An electromagnetic conductivity map (EM38 - horizontal mode) for the saltbush site is shown in Figure 5. Table 3 shows the relationship between the severity of salinity, groundcover and EM conductance at this site.

Table 3. Salinity classes within saltbush site

Salinity class (mS/m)	Indicator Plant	EM conductance
mild	capeweed	< 70
moderate	barley grass	70 - 200
severe	samphire	> 200

Electromagnetic conductivity maps for the flooded site and trees on seep site are shown in Figures 6 and 7 respectively. At the flooded site sand and gravel beds associated with old

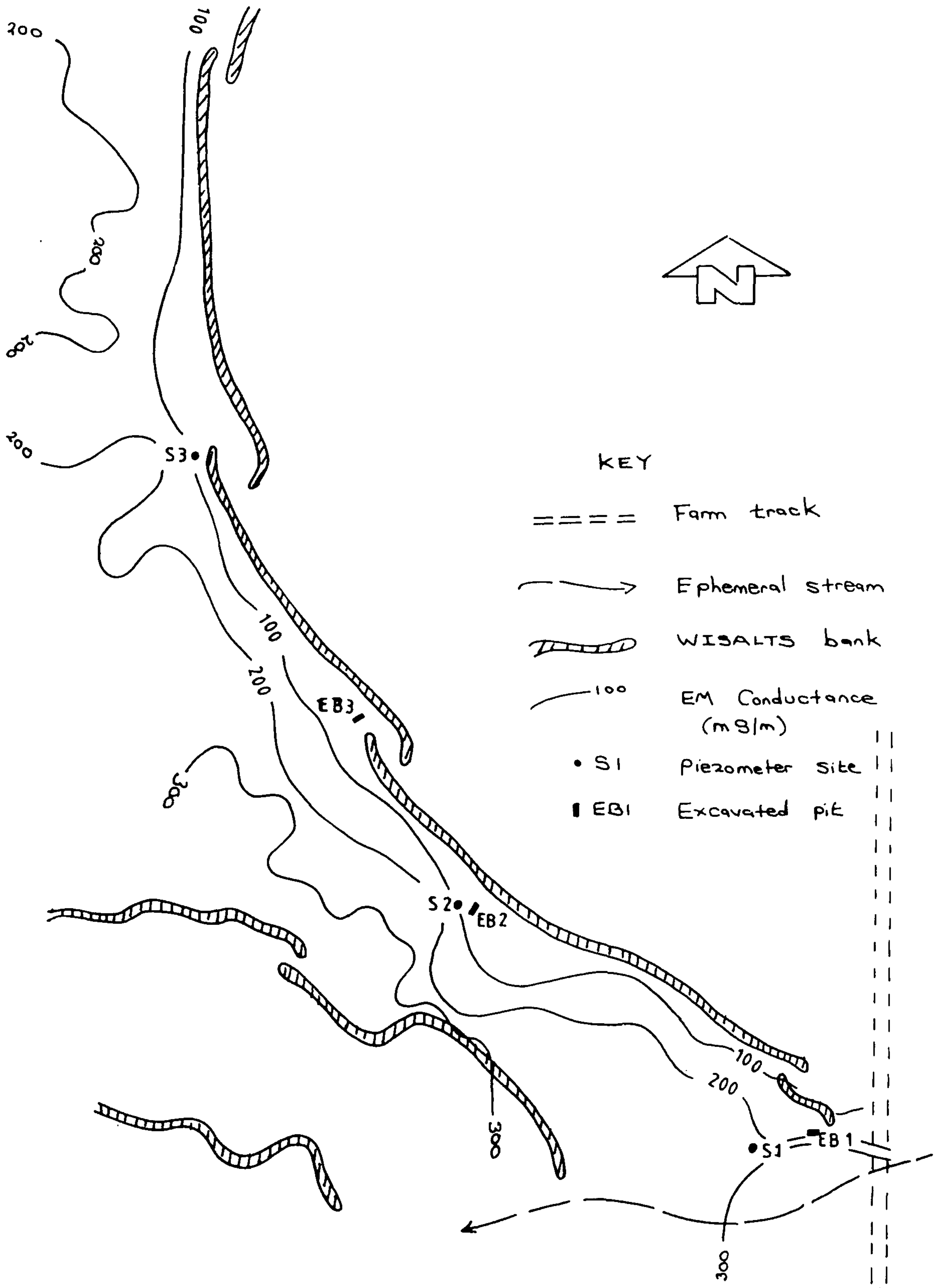


Figure 5 Electomagnetic conductance (EM38) of surface soils at saltbush site.

infilled drainage lines were observed in the broad valley floor. These areas were well defined by the electromagnetic method as EM conductance readings were significantly lower. At the trees on seep site subsoil salinity was apparent (EM38 - vertical mode) to the north and south of the sandplain seep anomaly indicating a potential for spread of surface salinity at this site. Because of deep and relatively coarse textured soils in the sandplain seep, an EM conductance greater than 30 mS/m represented a saline soil.

A cross-section of EM38 (horizontal and vertical modes) and magnetic data for the watertable monitoring site are shown in Figure 8. EM conductance was relatively low upslope of site W1 but increased sharply downslope of site W1. An absence of magnetic anomalies suggests that no dolerite dykes are present in this part of the valley.

6.2.5. Discussion

Hydrogeological investigations indicated the existence of at least three separate groundwater systems operating within the East Ballidu catchment.

6.2.5.1 Deep groundwater flow

A deep regional groundwater flow system occurring in pallid zone materials above bedrock. The upper confining bed for this groundwater was a hardpan of iron and silica cemented clayey sands. However, this apparent confining layer was observed to be a leaky bed and saline water was moving upwards into the lower soil profile in salinized areas of the lower valley. The mean EC of this groundwater system was 1,000 mS/m (Cl^- = 3,500 mg/L).

6.2.5.2 Perched groundwater flow

A perennial perched flow system developing on a "silcrete" hardpan beneath deep yellow sandplain. The aquifer was unconfined and hence was readily recharged by excess rainfall percolating beyond the root zone of crops and pastures in the coarse textured soils. This system was discharging water as seepage along the base of yellow sandhills. Although downward head gradients within the seep indicated the potential for downward leakage of unconfined water to recharge the deep groundwater system, this was not observed to be happening in the short term, due to poor hydraulic connection between the two aquifers. The mean EC of this unconfined groundwater was 55 mS/m (Cl^- = 180 mg/L). Although groundwater feeding the seep was relatively fresh, the salinity of water and soil within the seep was significantly greater due to concentration by evaporation of salt from the shallow watertables.

6.2.5.3 Shallow ephemeral watertables

An ephemeral shallow perched watertable developed seasonally at the A/B or B/C horizon interface where there was a significant texture contrast in the soil profile. This watertable developed on hillslopes and in the valley floor following heavy rainfall events and persisted for a few weeks or during the winter months. This shallower water may have potential to recharge deep groundwaters.

6.2.5.4 Groundwater responses

While shallow watertables and deep groundwater in the broad valley floor responsed rapidly to rainfall events, deeper groundwater in higher tributary valleys did not display a winter response. However, a delayed response of up to 6 months or longer may still occur. The rapid response of deep groundwater in the lower valley to rainfall may be due to a number of factors. It may indicate a pressure response caused by the semi-confining layer or rapid recharge as macropore flow along preferred channels.

High piezometric levels and the presence of a shallow seasonal watertable within the broad valley floor did not necessarily indicate that the soil was severely salt affected. The most reliable guide to the severity of salinity at a site was the summer/autumn depth of the permanent watertable and the salinity of this watertable.

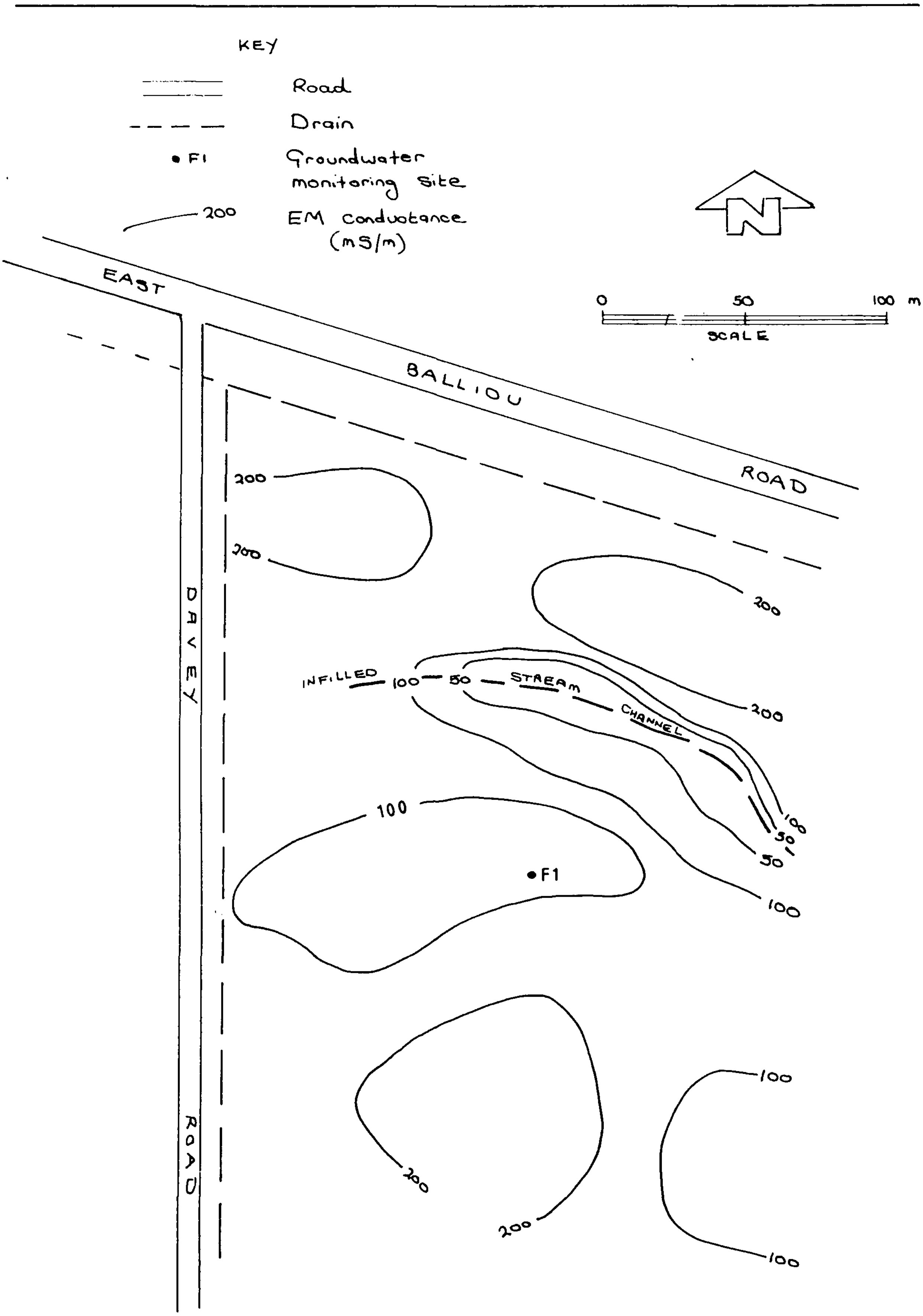


Figure 6 Electromagnetic conductance (EM38) of surface soil at the flooding site.

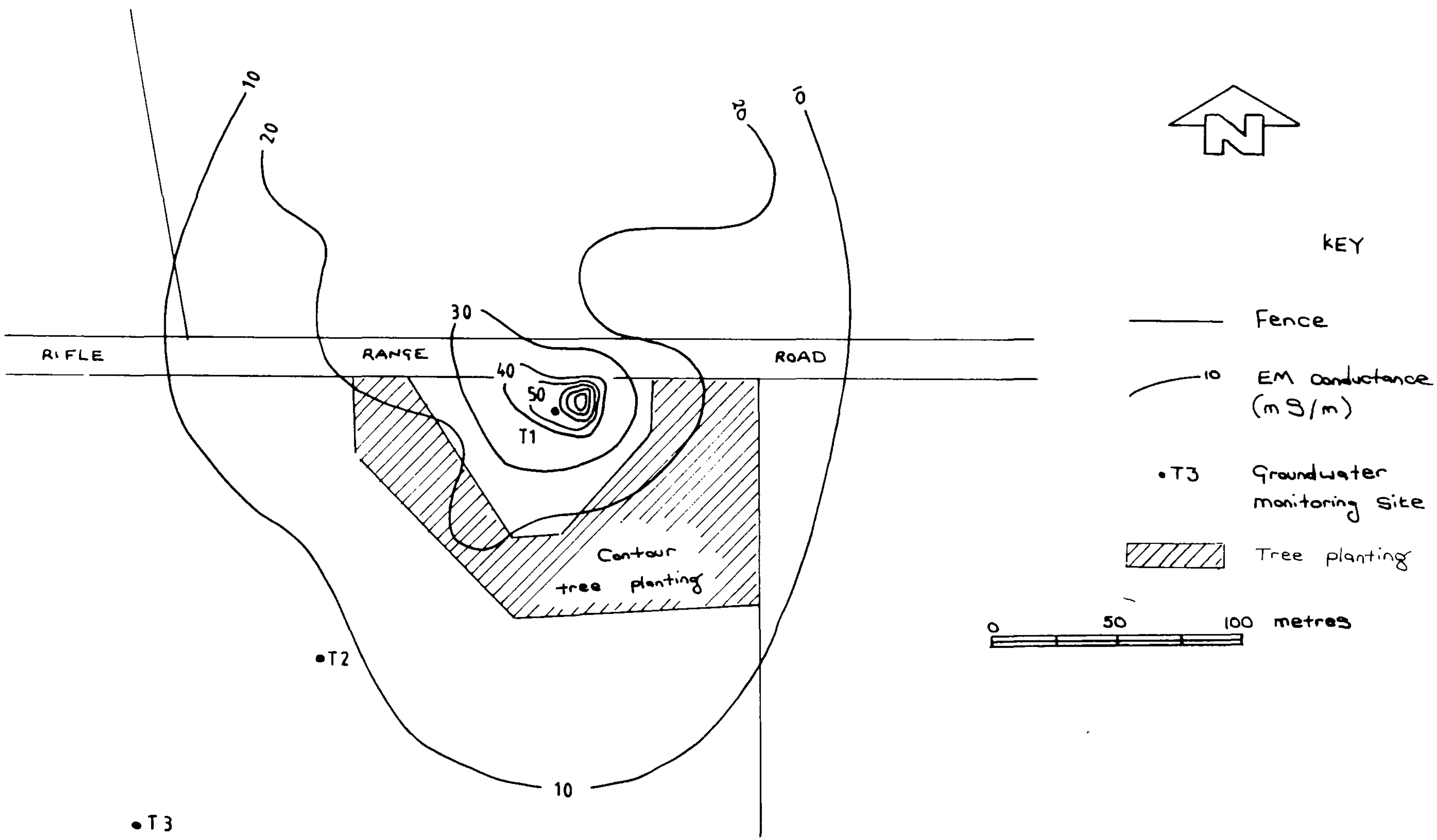


Figure 7 Electromagnetic (EM38) conductance of surface soils at trees on seep site.

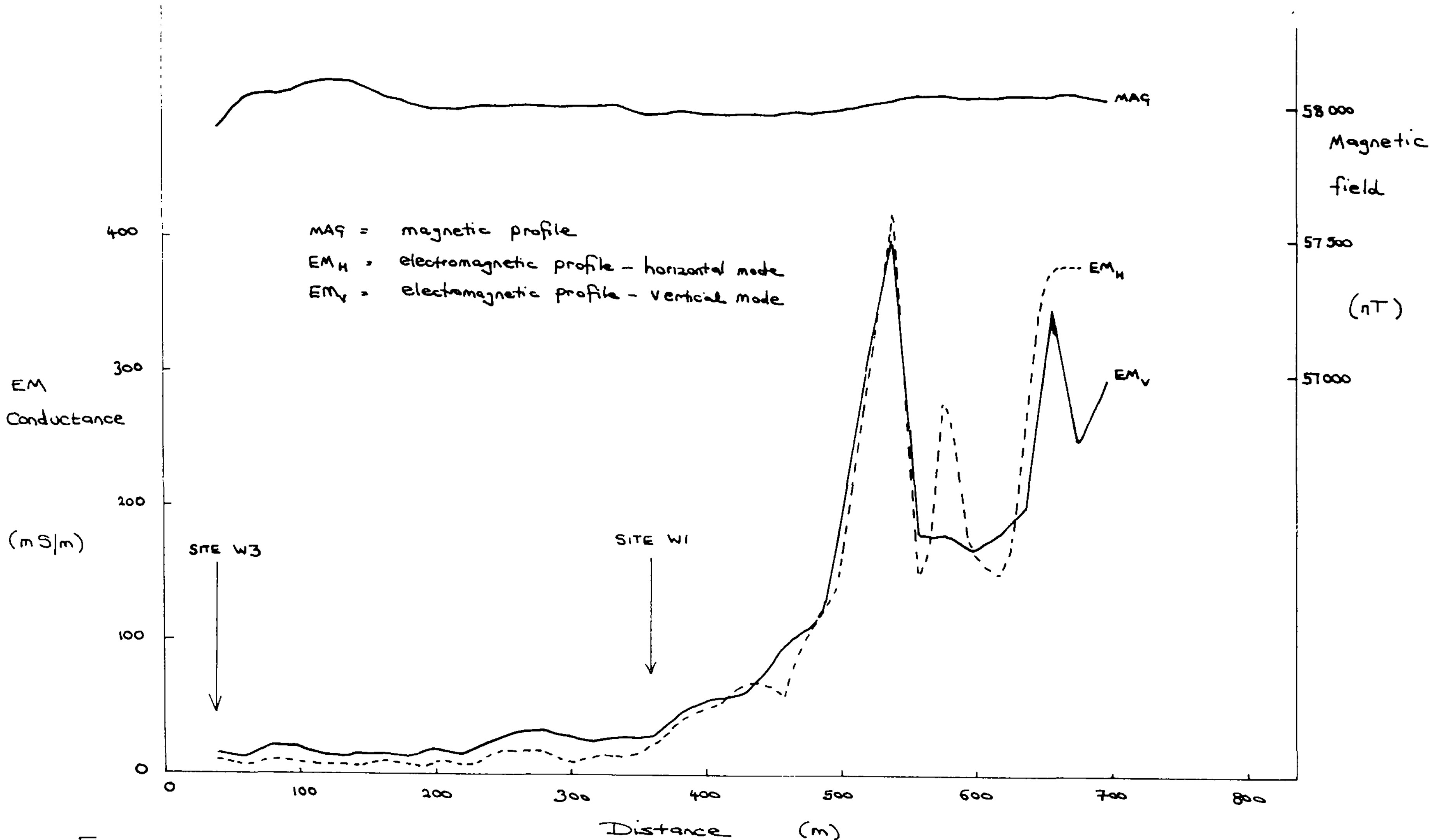


Figure 8 Electromagnetic (EM38) and magnetic profiles for watertable monitoring site.

6.2.5.5 Groundwater management options

Planting of saltbush and improved drainage in the broad valley floor will not significantly reduce the piezometric surface and will probably have minimal effect on the shallow regional watertable. The chief benefits would be to reduce the effects of winter flooding and waterlogging and summer evaporation from a bare soil surface. This in itself should help to prevent land degradation from spreading and becoming more severe. However, downward hydraulic gradients during winter indicates that in situ recharge could be occurring even in saline discharge areas. Hence reduction o shallow watertables using mechanical and biological drains would seem profitable. Shallow drains will help remove excess surface water and planting of salt tolerant trees in mildly saline areas will help to lower shallow watertables.

Planting of trees upslope of sandplain seeps should intercept perched unconfined flow to the seep and hence dry out the seep within 3 to 5 years. It is recommended that the tree planting be extended northwards along the flanks of a yellow sandhill at the trees on seep site.

Zones of low EM conductance on the broad valley floor (flooding site) could indicate areas of localized or point source recharge in the landscape because salt has been effectively leached out of the profiles in these sandier areas. These would be logical areas to plant high water use trees (Bullock and Williams, 1987).

6.2.6. REFERENCES

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6.2.7. ACKNOWLEDGEMENTS

The assistance of M. Lang in field survey work and water sample analysis, and B. Wren for laboratory analysis of soil samples is gratefully acknowledged.

6.3

EAST BALLIDU CATCHMENT: PEAK FLOOD ESTIMATION
Edward Hauck

Design Considerations for Land Conservation Earthworks

Land conservation earthworks are designed to perform an intended function within limits characterized by the runoff or rainfall generated from a design storm over a defined catchment area. Design storms are referred to by their average recurrence interval (AIR, yr) or the expected value of the period between excedances of a given discharge. Choosing an appropriate design storm depends on a combination of factors which include the benefits from earthworks installation, cost of earthworks, the potential damage caused by earthworks failure and the finantial constraints of the landholder or group of landholders. Land conservation earthworks are often based on ARIs of up to 20 years where risk of failure is accepted.

Two important aspects of design storms are the peak runoff rate (m3/s) and the runoff volume (m3). Peak runoff rates are used to dimension channels (e.g. grade banks, drainage channels, waterways and dam spillways) such that non-erosive water velocities are maintained. Runoff volumes are required to determine the design capacity of water retension structures (e.g. absorption banks and dams).

This report presents estimates of peak runoff rates for the 17 sub-catchments east of the town of Ballidu (Figure 1) that are collectively referred to as the East Ballidu Catchment.

Estimates of peak flow rates for design storms with ARIs of 2, 5, 10, 20 and 50 years are presented for both sub-catchment outlets and the main drainage line at sub-catchment outlets.

Peak Flood Estimation

As recommended in the Soil Conservation Earthworks Design Manual (Bligh 1989), the Index Flood Method is used for peak runoff rate estimation. A note of caution regarding the accuracy of these estimates should be heeded. An error range in the order of 115% to 55% has been assessed (Pilgrim, 1987) and as such, further interpretation of estimates based on local knowledge of an area's ability to generate runoff may be warranted.

Assumptions

The following assumptions should be carefully considered when using the results presented in this report.

1. All sub-catchments are assumed to be 95 per cent cleared.

2. The effect of banks are not considered.

3. Drainage lines and sub-catchment boundaries (and areas) are as defined in Figure 1 and Table 1.

Index Flood Method

The Index Flood Method for loamy and lateritic soil catchments in wheatbelt regions was defined by Flavell et al. (1987) and Pilgrim (1987) as represented in the equation.

$$Q5 = 0.304\, A^{0.60}\, 10^{0.0052\, C_L}$$

where Q5 = peak flow rate (m3/s) for an ARI of 5 years
A = catchment area (km2)
C = clearing measured as a percentage of the catchment area.

Using the sub-catchment areas in Table 1 and the frequency factors in Table 2, estimates for sub-catchment peak flows were calculated (Table 3).

Table 1. East Ballidu sub-catchment data

Sub-catchment	Area, A (km2)	Stream length, L (km)	Time of concentration, tc (h)
A	44.5	11.8	3.22
B	40.6	11.3	3.10
C	31.6	8.6	2.82
D	8.7	4.8	1.73
E	8.4	6.5	1.71
F	21.6	6.3	2.44
G	4.8	3.8	1.38
H	5.0	3.2	1.40
I	43.2	14.1	3.18
J	20.4	5.2	2.39
K	17.2	4.1	2.24
L	22.4	9.4	2.48
M	40.2	9.2	3.09
N	15.5	7.3	2.15
O	26.0	11.1	2.62
P	16.6	5.9	2.21
Q	45.4	10.1	3.24

Table 2. Index Flood Method frequency factors (CY/C5) for loamy and lateritic soil catchments in the wheatbelt region.

ARI (yr)	2	5	10	20	50
CY/C5	0.50	1.00	1.76	3.05	5.65

Table 3. Estimated peak flow (m3/s), at sub-catchment outlets

Sub-catchment and drainage line	ARI (yr) 2	5	10	20	50
A-11	4.6	9.2	16.3	28.2	52.2
B-10	4.4	8.7	15.4	26.7	49.4
C-12	3.8	7.5	13.2	23.0	42.5
D- 9	1.7	3.5	6.1	10.6	19.6
E- 8	1.7	3.4	6.0	10.4	19.2
F-13	3.0	6.0	10.5	18.3	33.9
G- 7	1.2	2.4	4.3	7.4	13.7
H- 6	1.2	2.5	4.4	7.6	14.1
I- 5	4.5	9.1	16.0	27.7	51.3
J-14	2.9	5.8	10.2	17.7	32.7
K-15	2.6	5.2	9.2	15.9	29.5
L- 4	3.1	6.1	10.8	18.7	34.6
M- 3	3.5	8.7	15.3	26.5	49.1
N- 2	2.5	4.9	8.6	15.0	27.7
O-16	3.3	6.7	11.8	20.4	37.8
P- 1	2.6	5.1	9.0	15.6	28.9
Q-17	4.7	9.4	16.5	28.5	52.9

The estimated peak flow rates for the main drainage line in Table 5 were derived using equation 1 and Tables 2 and 4. Time of concentration (tc) data listed in Tables 3 and 5 give an approximation of the time required for water to flow from the most remote point of the catchment to the catchment outlet.

Table 4. East-Ballidu main drainage line data

Sub-catchment (drainage line no.)	Total upstream area, A (km2)	Main stream length, L (km)	Time of concentration, tc (h)
A-11	-	-	-
B-10	-	-	-
C-12	116.7	11.6	4.63
D- 9	125.4	13.1	4.77
E- 8	133.8	16.3	4.89
F-13	155.4	17.5	5.17
G- 7	160.2	17.8	5.23
H- 6	165.2	21.0	5.29
I- 5	208.4	22.0	5.78
J-14	228.8	23.8	5.99
K-15	246.0	26.3	6.16
L- 4	268.4	28.1	6.36
M- 3	308.6	32.3	6.71
N- 2	324.1	35.3	6.84
O-16	350.1	37.7	7.04
P- 1	366.7	39.2	7.17
Q-17	412.1	40.7	7.49

Table 5. Estimated peak flow (m3/s) for the main drainage line immediately down-stream of sub-catchment outlets

Sub-catchment	ARI (yr)				
A-11	-	-	-	-	-
B-10	-	-	-	-	-
C-12	8.2	16.5	29.0	50.3	93.1
D- 9	8.6	17.2	30.3	52.5	97.3
E- 8	8.9	17.9	31.5	54.6	101.1
F-13	9.8	19.6	34.5	59.7	110.6
G- 7	10.0	19.9	35.1	60.8	112.6
H- 6	10.2	20.3	35.7	61.9	114.7
I- 5	11.7	23.3	41.1	71.2	131.9
J-14	12.3	24.7	43.4	75.2	139.3
L- 4	13.6	27.2	47.8	82.9	153.5
M- 3	14.8	29.5	52.0	90.1	166.9
N- 2	15.2	30.4	53.6	92.8	171.9
O-16	15.9	31.9	56.1	97.2	180.1
P- 1	16.4	32.8	57.7	99.9	185.1
Q-17	17.6	35.1	61.9	107.2	198.6

Summary

Estimated peak flow rates for East Ballidu sub-catchments and the catchment's main drainage line were derived suing the Index Flood Method. This data set will be of use when considering design options for land conservation earthworks.

Acknowledgements

Richard Steckis and the GIS group are acknowledged for their efforts in mapping the sub-catchments and drainage lines of the East Ballidu Catchment.

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7 FUTURE RESEARCH

7.1 The East Ballidu Land Conservation District should encourage increased water use and efficient use of crops, pastures trees and saltbush.

Research into deep rooting perennial species for recharge areas is required.

Lupin problems such as Pleochaeta root rot, brown spot, Rhizoctonia root rot need to be researched so that cropping systems using lupins can be sustained.

Soil loss with grazing lupin should be quantified.

7.2 A long term programme to monitor the water table needs to be carried out to help determine future trends in salinity.

7.3 The regional hydrology of the area should be researched to determine the effect of the metamorphased western end of the catchment on the water table trends.

7.4 An economic study should be carried out to determine if all the farmers in the area can carry out the necessary works and remain viable.

8. ACKNOWLEDGEMENTS

Thanks are due to:
The Chairman, Committee and members of the East Ballidu Soil Conservation District.
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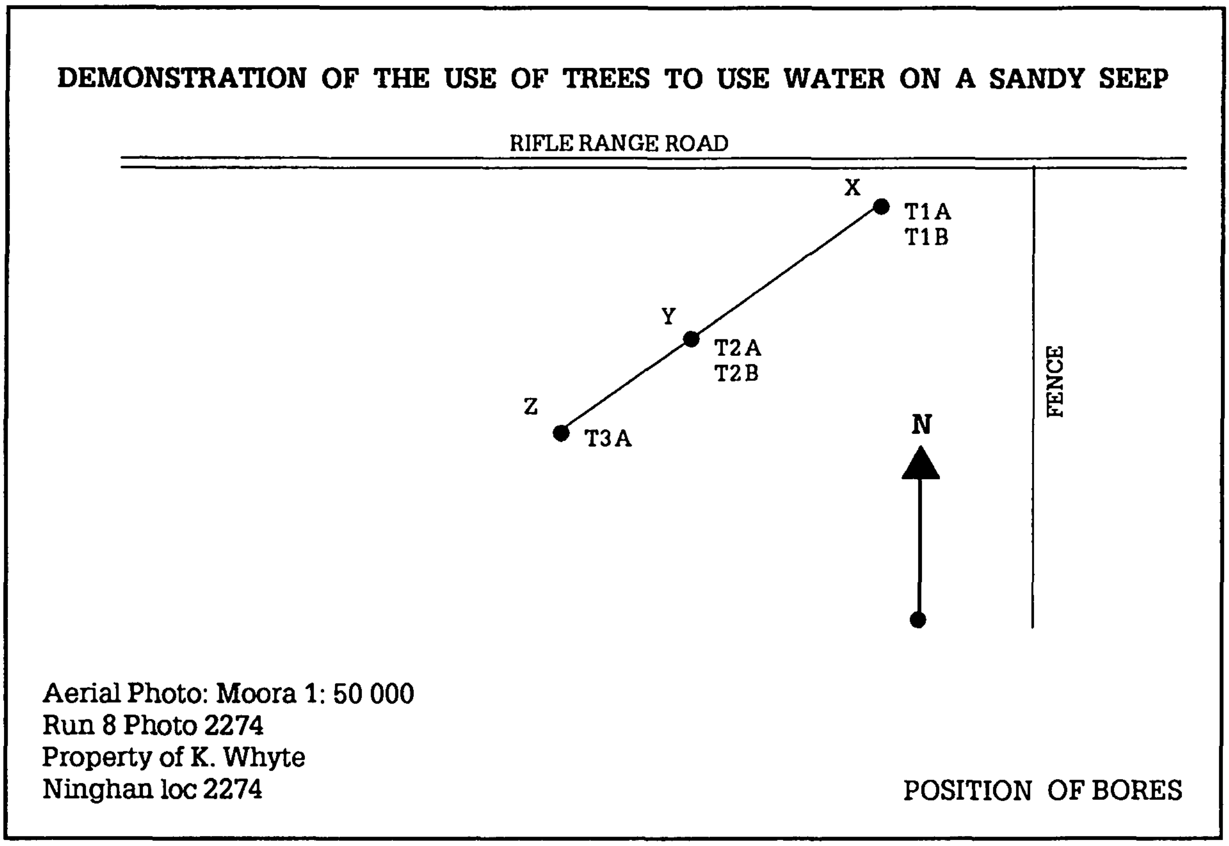
The Department of Conservation and Land Management is thanked for its participation in a field day in the area.

APPENDIX 1

LOCATION OF DEMONSTRATION SITES

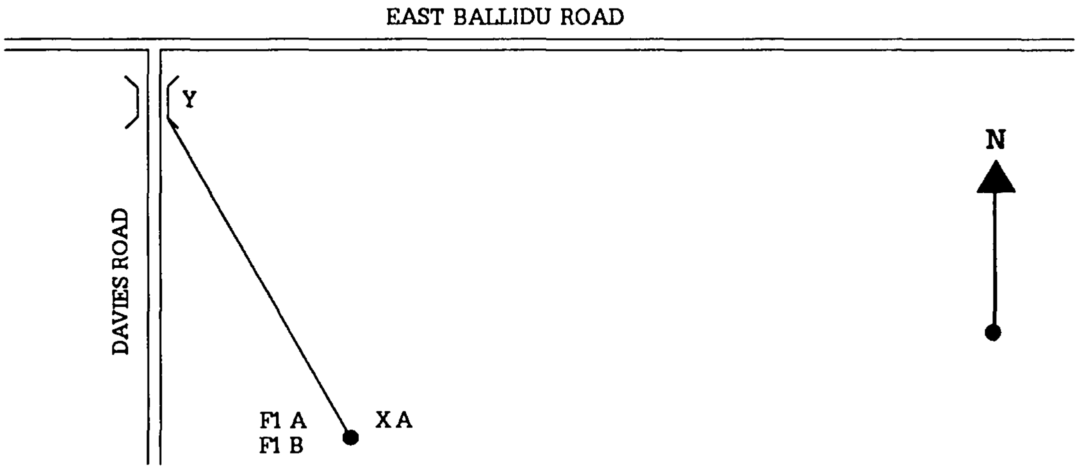
The diagrams show the location of demonstration sites.
Six demonstration sites have been established:

1. The use of trees to manage a seepage site.



2 A site to assess the effects of intermittent flooding on the water table as a process of salinization.

EFFECT OF FLOODING ON WATER TABLE - RISE & SALINITY



Aerial Photo: Moora 1: 50 000
Run 9 Photo 5334
Property of D. Whyte
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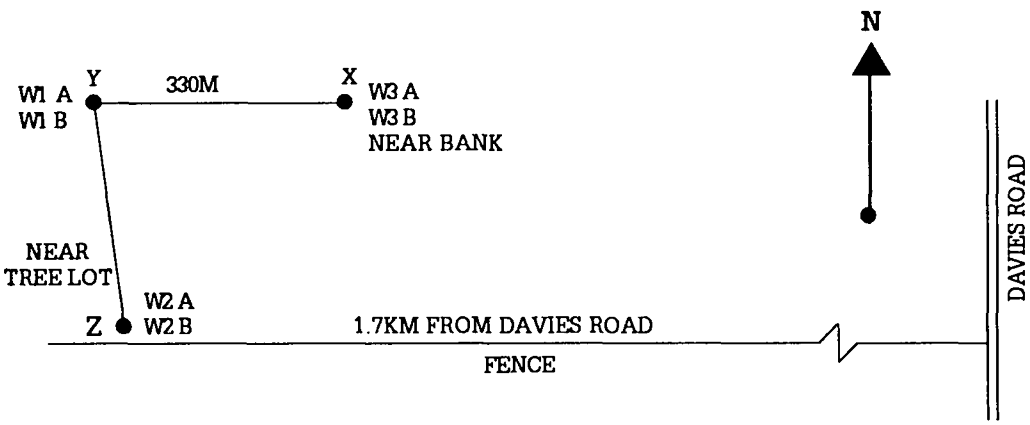
POSITION OF BORES

3. A site using bores to measure water table development as an indication of potential salinity.

DEMONSTRATION OF WATER TABLE AS EARLY INDICATION OF POTENTIAL SALINITY



Aerial Photo: Moora 1: 50 000
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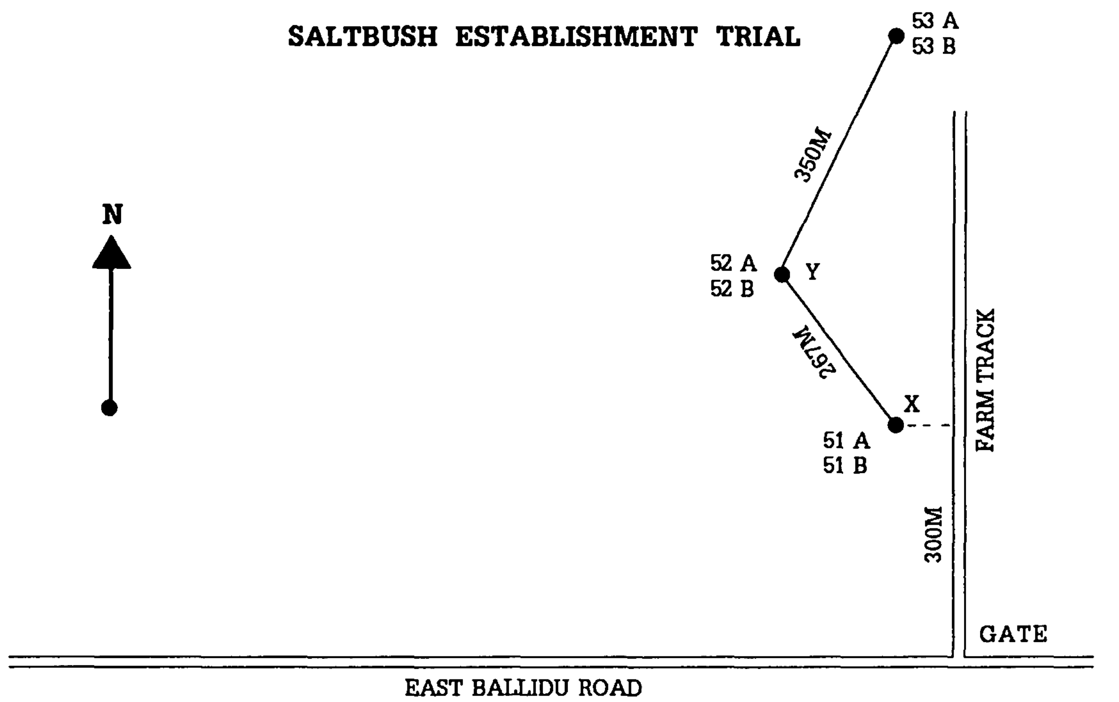
POSITION OF BORES

4. Saltbush management on a saline area.



Aerial Photo: Moora 1: 50 000
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Property of V. Campbell
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POSITION OF BORES

APPENDIX 2

Physical and chemical properties of soil samples from drill holes

Site	Depth (m)	Gravel (%)	pH 1:5 H_2O	$EC_{1:5}$ (mS/m)	$Cl^-_{1:5}$ (%)
S1	0.5	3	7.5	128	0.18
	1.0	2	8.5	176	0.25
	1.5	5	8.4	111	0.15
	2.0	2	8.3	71	0.08
	2.5	9	8.0	70	0.07
	3.0	10	7.5	57	0.06
	3.5	11	6.7	53	0.06
	4.0	10	7.0	54	0.07
	4.5	6	6.8	54	0.07
	5.0	19	6.4	48	0.07
	5.5	9	6.4	53	0.07
	6.0	22	6.1	63	0.09
	6.5	10	5.8	89	0.13
	7.0	30	6.2	60	0.09
	7.5	24	6.3	64	0.09
S3	0.5	30	6.2	32	0.04
	1.0	15	6.2	38	0.05
	1.5	18	6.8	26	0.03
	2.0	16	7.4	25	0.03
	2.5	14	7.3	27	0.03
	3.0	19	7.2	25	0.02
	3.5	11	7.2	20	0.02
	4.0	22	6.6	30	0.04
	4.5	28	6.0	39	0.05
	5.0	15	5.5	46	0.07
	5.5	12	5.2	63	0.09
	6.0	13	5.3	64	0.09
	6.5	10	5.1	83	0.13
	7.0	24	5.4	60	0.09
	7.5	12	5.4	101	0.11
	9.5	0	5.1	162	0.25
	11.0	2	5.3	88	0.13
	16.0	3	5.8	58	0.09
	17.5	1	5.9	34	0.05
T1	0.5	0	5.8	65	0.07
	1.0	28	6.2	66	0.07
	1.5	21	6.3	44	0.06
	2.0	24	6.8	34	0.05
	2.5	34	7.4	28	0.04
	3.0	32	8.4	28	0.03
	3.5	27	8.3	29	0.03
	4.0	6	8.9	31	0.02
	4.5	1	8.4	28	0.02
	5.0	3	8.2	27	0.03
	5.5	0	8.3	27	0.03
	6.0	1	8.4	34	0.03
	6.5	0	8.6	34	0.03
	7.0	0	8.8	34	0.04
	7.5	0	8.7	33	0.04

Site	Depth (m)	Gravel (%)	pH 1:5 H_2O	$EC_{1:5}$ (mS/m)	$Cl^-_{1:5}$ (%)
	8.0	0	8.6	35	0.04
	8.5	1	8.5	42	0.05
	9.0	1	8.3	55	0.06
	9.5	1	8.4	56	0.06
	10.0	1	7.7	132	0.15
	11.0	2	7.2	108	0.17
	12.0	3	7.2	200	0.35
W1	0.5	13	6.1	84	0.09
	1.0	10	6.6	27	0.02
	1.5	11	7.6	20	0.02
	2.0	17	8.7	10	0.01
	2.5	25	8.7	14	0.02
	3.0	32	8.4	16	0.01
	3.5	16	8.6	19	0.02
	4.0	30	8.3	23	0.02
	4.5	36	8.5	25	0.03
	5.0	21	8.7	25	0.02
	5.5	15	8.0	35	0.03
	6.0	4	7.8	68	0.06
	6.5	6	7.6	77	0.08
	7.0	3	7.7	86	0.09
	7.5	14	5.4	101	0.11
	8.0	14	7.7	75	0.08
	8.5	5	7.4	121	0.14
	9.0	7	7.2	110	0.12
	9.5	3	7.1	96	0.11
	10.0	4	7.0	93	0.11
	11.5	1	7.1	151	0.18
	13.0	0	7.0	152	0.21
	15.0	0	7.0	159	0.19
	17.0	7	7.3	72	0.08

APPENDIX 3

Drilling logs

Site	Depth (m)	Profile description
S1	0 - 0.5	Sand over gleyed clay
	0.5 - 3.5	Mottled gleyed dense clay
	3.5 - 7.0	Hardpan - cemented clayey sand
	7.0 - 7.5	Pallid zone
S2	0 - 0.5	Sand over clay
	0.5 - 2.0	Grey-green clay
	2.0 - 2.5	Grey mottled sandy clay
	2.5 - 6.0	Hardpan - cemented sand
	6.0 - 7.5	Pallid zone - soft white kaolin with indurated layers
S3	0 - 0.5	Grey sand over gravelly clay
	0.5 - 1.5	Laterite gravel
	1.5 - 2.5	Mottled greenish - yellow clay
	2.5 - 4.5	Hardpan - cemented sandy kaolin
	4.5 - 16.0	Mottled zone - red clayey sand with indurated layers
	16.0 - 17.5	Pallid zone - soft cream gritty kaolin
F1	0 - 0.5	Brown sand
	0.5 - 1.5	Mottled gleyed clay
	1.5 - 2.5	Red-brown tight sandy clay
T1	0 - 0.5	Brown sandy loam
	0.5 - 1.0	Yellow clayey sand
	1.0 - 2.5	Lateritic gravel
	2.5 - 5.0	Hardpan - cemented grey sand
	5.0 - 12.0	Pallid zone - soft grey kaolin
	12.0 - 12.7	Saprolite - cream gritty clay with micaceous rock fragments
	12.7	Bedrock - (schist?)
T2	0 - 0.5	Yellow brown loamy sand
	0.5 - 1.8	Yellow clayey sand, saturated at 1.5 m
	1.8 - 4.5	Hardpan - (silicrete?)
	4.5 - 7.5	Pallid zone
T3	0 - 0.5	Yellow brown loamy sand
	0.5 - 3.0	Yellow clayey sand
	4.5 - 5.0	Gravelly sand
	5.0 - 5.2	Hardpan - (silicrete?)
W1	0 - 0.5	Grey brown sandy loam over sandy clay
	0.5 - 1.5	Laterite gravel
	1.5 - 6.0	Hardpan - cemented clayey sand
	6.0 - 15.5	Pallid zone - soft cream kaolin
	15.5 - 17.0	Saprolite - rock fragments
	17.0 - 17.5	Saprolite - dark grey tight gritty clay

W2	0	- 0.5	Yellow loamy sand
	0.5	- 2.0	Laterite gravel
	2.0	- 3.0	Mottled sandy clay
	3.0	- 6.5	Hardpan - cemented clayey sand
	6.5	- 9.5	Pallid zone - white gritty kaolin
W3	0	- 0.5	Brown gravelly loamy sand
	0.5	- 1.5	Lateritic gravel
	1.5	- 7.0	Hardpan - cemented sand
	7.0	- 7.5	Pallid zone - yellow sandy clay

APPENDIX 4

Soil profile descriptions for site characterization

Profile:	EB1 (Saltbush site - severe)
Location:	Wongan 1:100,000 AMG 491400 6617000
Slope category:	Level, (< 1%)
Morphological type:	Flat
Soil classification:	Great soil group: SK Principal profile form: Dy 1.41

Soil profile description

A11	0-10 cm	Dark greyish brown (10YR 4/2) clayey coarse sand, surface crust and saline, weak pedality, polyhedral structure, sandy fabric, pH 5.8, sharp change to -
A12	10-18 cm	Yellowish brown (10YR 5/4) sandy loam, weak pedality, polyhedral structure, earthy fabric, pH 5.9, abrupt change to -
A2	18-22 cm	Conspicuously bleached A2 horizon: Light brownish grey (10YR 6/2 moist) light grey (10YR 7/2 dry) sandyloam, weak pedality, polyhedral structure, sandy fabric, pH 5.5, abrupt change to -
B21	22-32 cm	Mottled light yellowish brown (10YR 6/4 - mottle 2% orange) light medium clay, moderate sub-angular blocky structure, rough-faced peds, pH 5.3, gradual change to -
B22	32-65cm	Mottled light yellowish brown (10YR 6/4 - mottle 2% brown and orange) medium clay, moderate sub- angular blocky structure, rough-faced peds, pH 5.1, gradual change to-
C	65-110 + cm	Mottled pale yellow (5Y 7/3 - mottle 20% red and orange) medium clay, strong sub-angular blocky structure, smooth faced peds, ferruginous concretions (20%) in a weakly cemented matrix, pH 5.2.

Profile:	EB2 (Saltbush site - moderate)
Location:	Wongan 1:100,000 AMG 491200 6617100
Slope category:	Level, (< 1%)
Morphological type:	Flat
Soil classification:	Great soil group: SE Principal profile form: Gn 1.82

Soil profile description:

A11	0-14 cm	Greyish brown (2.5Y 5/2) clayey coarse sand, saline surface crust, apedal, massive structure, sandy fabric, pH 5.9, sharp change to -
A12	14-31 cm	Mottled pale yellow (2.5Y 7/4 - mottle 2% orange)sandy loam, apedal, massive structure, sandy fabric, pH 5.7, abrupt change to -
B1	31-47 cm	Mottled pale yellow (2.5Y 7/4 - mottle 2% orange)sandy clay loam, weak pedality, polyhedral structure, sandy fabric, ferruginous gravel (20-50%), pH 6.4, abrupt change to -
BC	47-65 cm	Mottled light grey (5Y 7/2 - mottle 20-50% red) light clay, rough-face sub-angular blocky peds, moderate structure, ferruginous gravel (2%) in a weakly cemented matrix pH 6.5

Profile:		EB3 (Saltbush site - mild)
Location:		Wongan 1:100,000 AMG 491100 6617200
Slope category:		Very gently inclined (1%)
Morphological type:		Lower-slope
Soil classification:		Principal profile form: Gn 1.82

Soil profile description:

A11	0-10 cm	Greyish brown (2.5Y 5/2) clayey coarse sand, surface crust, apedal, massive structure, sandy fabric, pH 6.3, abrupt change to -
A12	10-22 cm	Light yellowish brown (2.5Y 6/4) sandy loam, weak pedality, polyhedral structure sandy fabric, pH 5.9, clear change to -
B21	22-38 cm	Mottled pale yellow (2.5Y 7/4 - mottle 20% orange) sandy clay loam, weak pedality, polyhedral structure, sandy fabric, ferruginous gravel (2%), pH 6.6, abrupt change to -
B22	38-57 cm	Mottled pale yellow (5Y 7/3 - mottle 2% orange) clay loam coarse sandy, weak pedality, polyhedral structure, sandy fabric, ferruginous gravel (20%), pH 6.6, clear change to -
C	57-80 cm	Mottled yellow (5Y 7/6 - mottle 20-50% red) sandy clay, weak pedality, polyhedral structure, sandy fabric, ferruginous concretions (20%) in a moderately cemented sesquioxide pan, pH 6.6

Profile:EB4		(Tree planting site)
Location:		Wongan 1:100,000 AMG 481400 6624200
Slope category:		Very gently inclined (1%)
Morphological type:		Lower-slope
Soil classification:		Great soil group: LP
Principal profile form:		Uc 2.12

Soil profile description:

A1	0-4 cm	Greyish brown (2.5Y 5/2) sandy loam, saline surface crust, weak pedality, polyhedral structure, sandy fabric, pH 6.7, abrupt change to -
A2	4-10 cm	Conspicuously bleaced A2 horizon: mottled light brownish grey (2.5Y 6/2 moist - mottle 2% orange) light grey (2.5Y 7/2 dry) sandy loam, weak polyhedral structure, sandy fabric, pH 6.6, clear change to -
B21	10-20cm	Mottled pale yellow (2.5Y 7/4 - mottle 10% orange) sandy loam, weak polyhedral structure, sandy fabric, pH 6.0, gradual change to -
B22	20-50 cm	Mottled yellow (2.5Y 7/6 - mottle 20% orange) sandy loam, weak polyhedral structure, sandy fabric, pH 6.3, abrupt change to -
B	50-80 cm	Ferruginuous gravel

APPENDIX 5

Chemistry of soil samples from excavated pits

Site	Depth (cm)	pH	$EC_{1:5}$ (mS/m)	Cl^- (%)	Sat[2] (%)	EC_e (mS/m)	CEC[3]	Ca^{++} (%)	Mg^{++} (%)	K^+ (%)	Na^+ (%)
ddd	33-333	3.3	333	3.33	33.3	3,333	3.3	33	33	3	33
EB1	0-10	5.8	57	0.07	16.4	1,086	2.1	25	40	7	19
	10-18	5.9	25	0.03	15.4	527	2.9	10	19	7	22
	18-22	5.5	35	0.04	17.5	668	2.0	8	19	4	13
	22-32	5.3	67	0.08	25.8	860	6.2	6	25	6	42
	32-65	5.1	128	0.16	37.2	1,197	9.6	7	29	7	51
	65-110	5.2	108	0.14	34.8	1,053	8.5	4	27	6	53
EB2	0-14	5.9	69	0.10	22.0	1,317	1.8	27	21	4	6
	14-31	5.7	40	0.06	20.2	763	1.6	14	16	5	4
	31-47	6.4	36	0.05	21.5	648	2.4	19	30	5	11
	47-65	6.5	59	0.08	31.7	691	5.0	17	27	8	19
EB3	0-10	6.3	9	0.01	26.5	131	2.1	38	15	4	5
	10-22	5.9	6	0.01	22.3	104	1.8	25	17	4	1
	22-38	6.6	6	0.01	26.3	78	2.3	27	27	4	1
	38-57	6.6	16	0.02	27.9	229	3.0	24	34	5	9
	57-80	6.6	23	0.03	33.9	248	4.0	21	41	6	14
EB4	0- 4	6.7	63	0.08	26.8	795	2.6	23	40	7	27
	4-10	6.6	13	0.02	21.1	186	2.1	17	14	15	14
	10-20	6.0	14	0.02	26.3	187	2.2	14	17	4	9
	20-50	6.3	4	0.01	23.5	56	1.7	17	22	5	2

1. pH (1:5 H20)
2. Saturation percentage.
3. Cation Exchange Capacity (m.e./100 g).