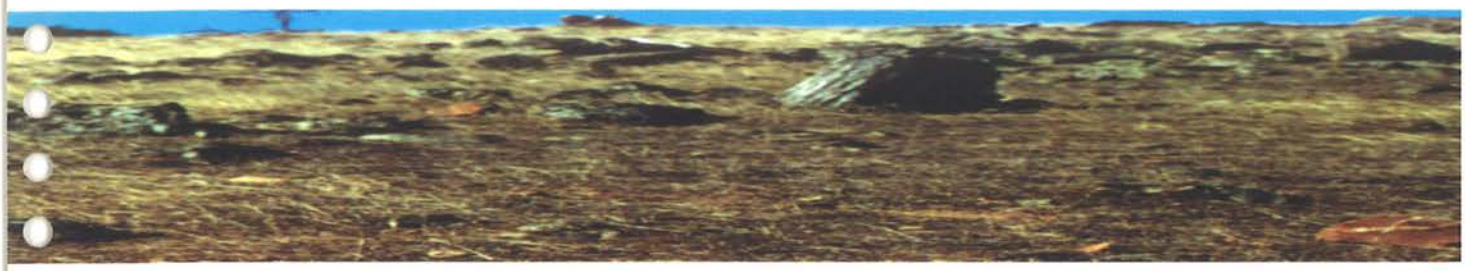
Catchment Management Series

Managing waterlogged and saline catchments in the Mt. Lofty Ranges, South Australia

A soil-landscape and vegetation key with on-farm management options



Rob Fitzpatrick, Jim Cox and John Bourne

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Contents

Water movement in catchments in the Mt. Lofty Ranges

The movement of water in catchments in the Mt. Lofty Ranges has changed over the last 200 years. Over-clearing has resulted in extra water moving through the soil, causing the groundwater to rise. Lower parts of catchments have become strongly waterlogged and salinity has increased.

Many soils are duplex, which are soils that show a sharp contrast between the top layer and the layer beneath, eg friable sandy loam over a firm clay. Water moving down through the top layer is often not able to penetrate the clay and so moves laterally above the clay layer. This water can cause the top layer to become waterlogged during winter.

The combination of waterlogging and salinity has reduced pasture production and stocking rates. In some cases lower parts of catchments have become bare, saline and eroded. Water movement through the soil also contains nutrients, chemical contaminants and dissolved organic carbon which can be transported by local streams and waterways into metropolitan water supplies.

By controlling water movement through the catchment then we also control salinity. Because water movement is very slow, control measures take a long time to be fully effective. It is important to identify problems and begin controlling them early.

The first step in managing the problem is to fence off saline or bare eroded areas and establish waterlogging tolerant and salt tolerant plants. The extra water moving either to groundwater or above the clay layer throughout the catchment must then be reduced by:

- establishing high water use perennial pastures, trees and/or shrubs, particularly in areas of high recharge.
- installing drains where necessary, to allow more effective pasture or crop establishment.

An easy way to decide which management options to use is by looking at your soils, especially the colour which will indicate excessive water movement through them. Some soils are unsuitable for drainage construction, and so it is necessary to make additional measurements to properly locate these options. Directly measuring soil salinity will better identify saline areas.

The Soil and Landscape Key

This key:

- Shows how to identify plant and soil features that are indicators of waterlogged and saline areas in high rainfall catchments in the Mt. Lofty Ranges.
- Suggests management options for improving productivity.
- Assists in identifying land capability classes used for property management planning.
- Is presented in an easy-to-follow form as it covers an area of related soil types, topography, hydro-geology and vegetation. Only selected soil features have been used to simplify the key. Similar keys are being developed for other areas.

All observations and measurements required are simple and inexpensive. Implementing management options will minimise the off-site impact of salt movement into streams, waterways and metropolitan water supplies.

Where it applies

The key applies to all duplex soils that receive about 500 mm or more annual rainfall and especially to soils that have been developed from the Kanmantoo geological formation (Figure 1).

If you notice waterlogged areas during the winter, or have bare, eroded gullies either on your farm or in your district, then this indicates you need to use this key to investigate the problem more closely.

A typical eroded gully at the bottom of a transect.

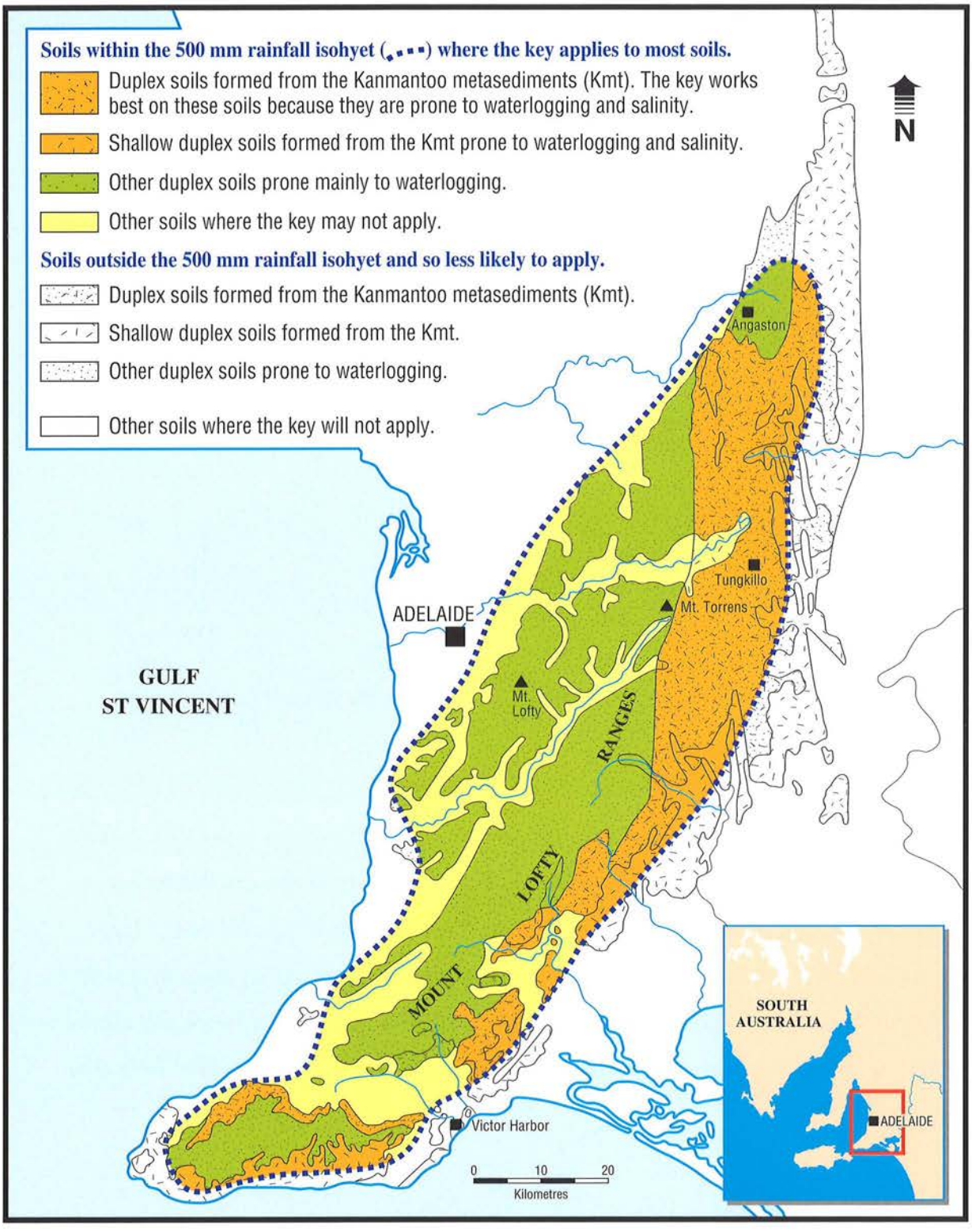


Figure 1: Areas in the Mt. Lofty Ranges covered by the key.

Before you start

What you will need

- Map or aerial photograph of farm/paddock with a scale ranging from 1:1000 to 1:5000.
- Two clear plastic sheet overlays.
- Tape or velcro to attach overlays to photograph.
- Coloured felt pens to write on overlays.
- Soil auger (post hole auger) or spade.
- Plastic or strong paper bags for soil sample collection.
- A blank Field Recording Sheet (See page 11 & 12)
- Rainwater.*
- 600 ml glass jars (e.g. vegemite jars) and a clean spoon.*
- Electrical conductivity meter.*
- pH meter or equivalent (optional).*

* Alternatively take samples to your local Primary Industries SA office or Landcare group

Planning where to go

On your property map or aerial photograph select several paths or transects across a paddock that is likely to have problems. These will usually be down a hillslope. Avoid transects that are not representative, eg fencelines or roadways. Mark the transects on the first plastic overlay (eg A-A^{1}, B-B^{1} in Figure 2). It may be helpful to add in any contour lines you have had surveyed, such as the 5 metre intervals used in Figure 2. An example sequence of soils, found down a slope, and associated problems that you may find, is shown in Figure 3. Typically not all of the soils shown will occur together.

Figure 3 →

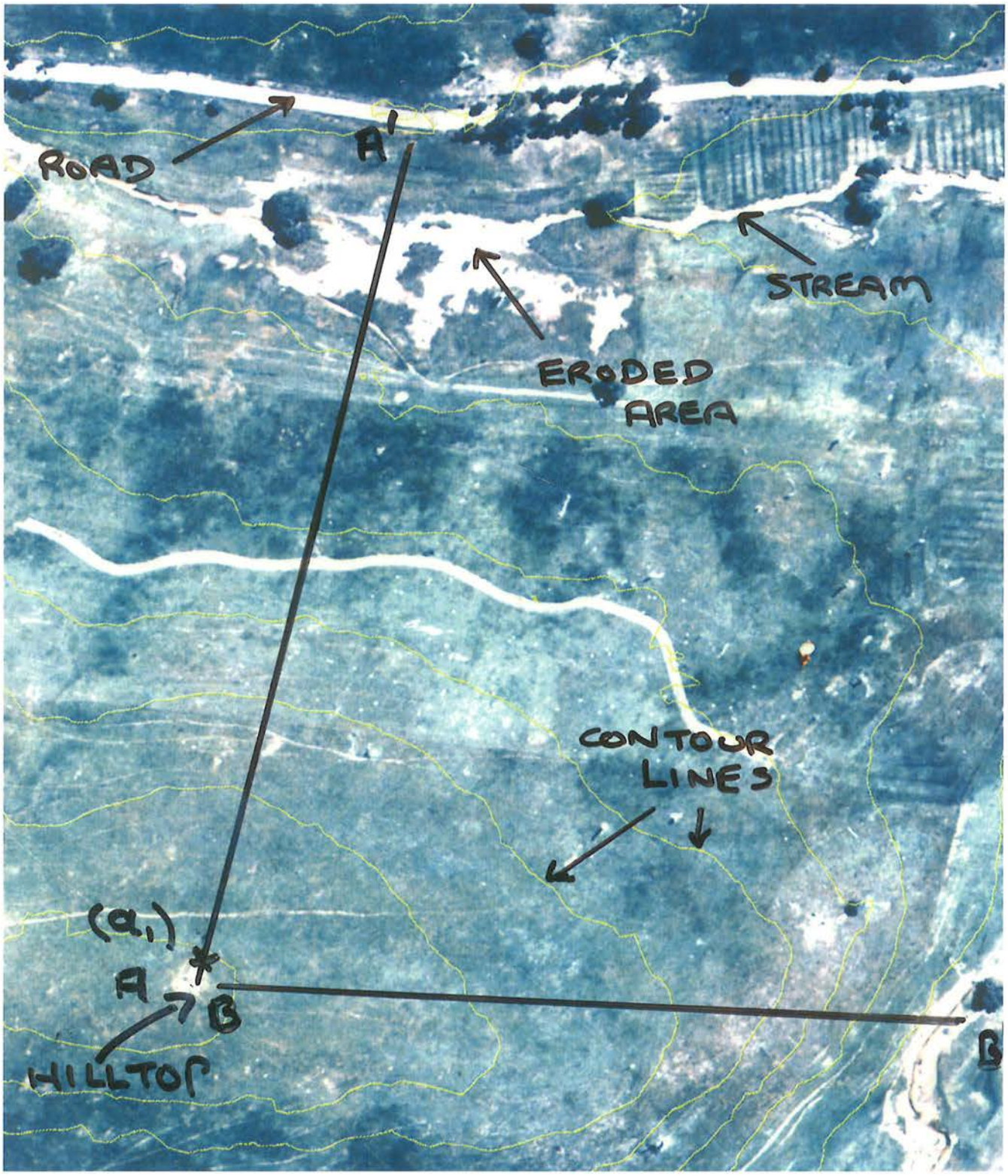


Figure 2: An example of two hand-drawn transects and other local features on a plastic overlay set over an aerial photograph.

Making observations in the field

1. Take this manual, copies of the blank Field Recording Sheet and map or aerial photograph with prepared overlay to the top of the transect to begin. Mark this point on the overlay and record it as observation point (a_1), (see Figure 2).
2. Tick appropriate boxes in column (a_1) on the Field Recording Sheet (see Figure 4 for a completed example).
3. Begin with recording vegetation and other surface features. Photographs in Appendix 1 on pages 19 and 24 will help you identify vegetation features.
4. Dig a hole with the soil auger or spade down into the hard clay/rock layer. If you are not sure how deep the hole should be, dig until soil consistence changes from loose or friable to firm or rigid. An explanation of soil consistence and how to estimate it is on pages 35 and 36. To see the change in soil features more easily, lay out the soil in a sequence on the ground as you dig it up.
5. Tick boxes against soil features on the Field Recording Sheet by matching with the photographs in Appendix 2 on pages 25 to 32. These follow the example slope sequence of soils in Figure 3. When the photograph matches your profile, the YES arrow indicates waterlogging duration and management options. If the photograph does not match follow the NO arrrow to the next page. The depth of soil layers along your transect can vary from those shown in the photographs.
6. Collect in a labelled bag approximately two cups of soil where suggested in the key, especially towards the bottom of the slope.
7. Repeat the above approximately every 30m down the slope or where landscape features change such as slope, vegetation or rockiness. Mark each subsequent point on the overlay (a_2), (a_3) *etc* (See Figure 5a). Tick the next column on the Field Recording Sheet.
8. Start a new Field Recording Sheet for each transect (eg B-B^1).
9. Measure salinity and sodicity on collected labelled samples back at the house or shed (see Appendix 3 on page 33 and 34). Record this information by ticking the boxes marked 'Additional Measurements' on the Field Recording Sheet for each transect.
10. Confirm and record on the Field Recording Sheet the soil type number referred to in the key (eg 1 to 8) at each observation point. Alternatively use the summary sheet of the key in Figure 3.

Figure 4: Example of a completed Field Recording Sheet

Date: 1/1/97											
Paddock: North											
Location of transect: Hill-top to road (A-A^1 in Figure 2)											
Observation point	(a_1)	(a_2)	(a_3)	(a_4)	(a_5)	(a_6)	(a_7)	(a_8)	(a_9)		
i **Vegetation & other surface features (See Appendix 1, pages 19-24)** Plants indicate well drained conditions	✔	✔									
Moderately waterlogged and low salt tolerant plants											
Strongly waterlogged and low salt tolerant plants			✔	✔							
Strongly waterlogged and high salt tolerant plants					✔	✔	✔	✔	✔		
Rock outcrops	✔										
Bare ground						✔	✔	✔			
Gully erosion							✔				
Salt crystals						✔	✔	✔			
Red stains or gels on the soil surface						✔		✔			

Observation point	(a_1)	(a_2)	(a_3)	(a_4)	(a_5)	(a_6)	(a_7)	(a_8)	(a_9)		
ii Soil features (See Appendix 2, pages 25-32) **Top layer; Consistence is loose, soft or friable**											
- brown	✔	✔									
- brown with grey mottles and red stains			✔								
- grey with red stains				✔	✔		✔		✔		
- bleached grey layer between top and bottom layer			✔	✔	✔				✔		
- black boggy, smelly and saline						✔		✔			
Bottom layer; Consistence is firm or rigid											
- red* (or red with yellow mottles)	✔	✔									
- yellow with red mottles											
- grey with yellow or red mottles			✔	✔	✔	✔	✔	✔	✔		
iii Additional measurements											
Salinity (1:5 Soil in water suspension is saline)											
- EC of top layer is above 0.4 dS/m					✔	✔	✔	✔	✔		
- EC of bottom layer is above 0.7 dS/m					✔	✔	✔	✔	✔		
Sodicity (1:5 Soil in water suspension)											
- partly cloudy (not sodic)											
- cloudy (medium)				✔							
- very cloudy (highly sodic)											
iv Soil type number from soil key or Figure 3	**1**	**2**	**4**	**5**	**6**	**7**	**8**	**7**	**6**		

* could also be yellow

Blank Field Recording Sheet

Date:											
Paddock:											
Location of transect:											
Observation point											
i **Vegetation & other surface features (See Appendix 1, pages19-24)** Plants indicate well drained conditions											
Moderately waterlogged and low salt tolerant plants											
Strongly waterlogged and low salt tolerant plants											
Strongly waterlogged and high salt tolerant plants											
Rock outcrops											
Bare ground											
Gully erosion											
Salt crystals											
Red stains or gels on the soil surface											

Observation point	(a_1)	(a_2)	(a_3)	(a_4)	(a_5)	(a_6)	(a_7)	(a_8)	(a_9)		
ii Soil features (See Appendix 2, pages 25-32) **Top layer; Consistence is loose, soft or friable**											
- brown											
- brown with grey mottles and red stains											
- grey with red stains											
- bleached grey layer between top and bottom layer											
- black boggy, smelly and saline											
Bottom layer; Consistence is firm or rigid											
- red* (or red with yellow mottles)											
- yellow with red mottles											
- grey with yellow or red mottles											
iii Additional measurements											
Salinity (1:5 Soil in water suspension is saline)											
- EC of top layer is above 0.4 dS/m											
- EC of bottom layer is above 0.7 dS/m											
Sodicity (1:5 Soil in water suspension)											
- partly cloudy (not sodic)											
- cloudy (medium)											
- very cloudy (highly sodic)											
iv Soil type number from soil key or Figure 3											

* could also be yellow

Mapping your observations and making management decisions

- From information recorded on the Field Recording Sheets now locate the boundary of each soil on the first plastic overlay and write in the soil number. As you will only have information from a few selected transects you will have to make some estimate of the soil boundaries from vegetation and contours. (See Figure 5a)
- Then select management options associated with each of the soil profile photographs in the key, or the example slope sequence in Figure 3. Record your management decisions, with appropriate boundaries, on the second plastic overlay. (See Figure 5b) A useful set of symbols is;

Plant shrubs & trees 

Alley farming or Agroforestry 

Plant with salt tolerant shrubs & trees 

Perennial pasture 

Salt tolerant grasses and saltbush 

Lime 

Native shrubs and grasses to stabilise gully banks 

Fence 

Interceptor drain and direction of flow 

Exclude stock 

Control structure in gully 

(You may want to write in the actual species or stock management after the symbol.)

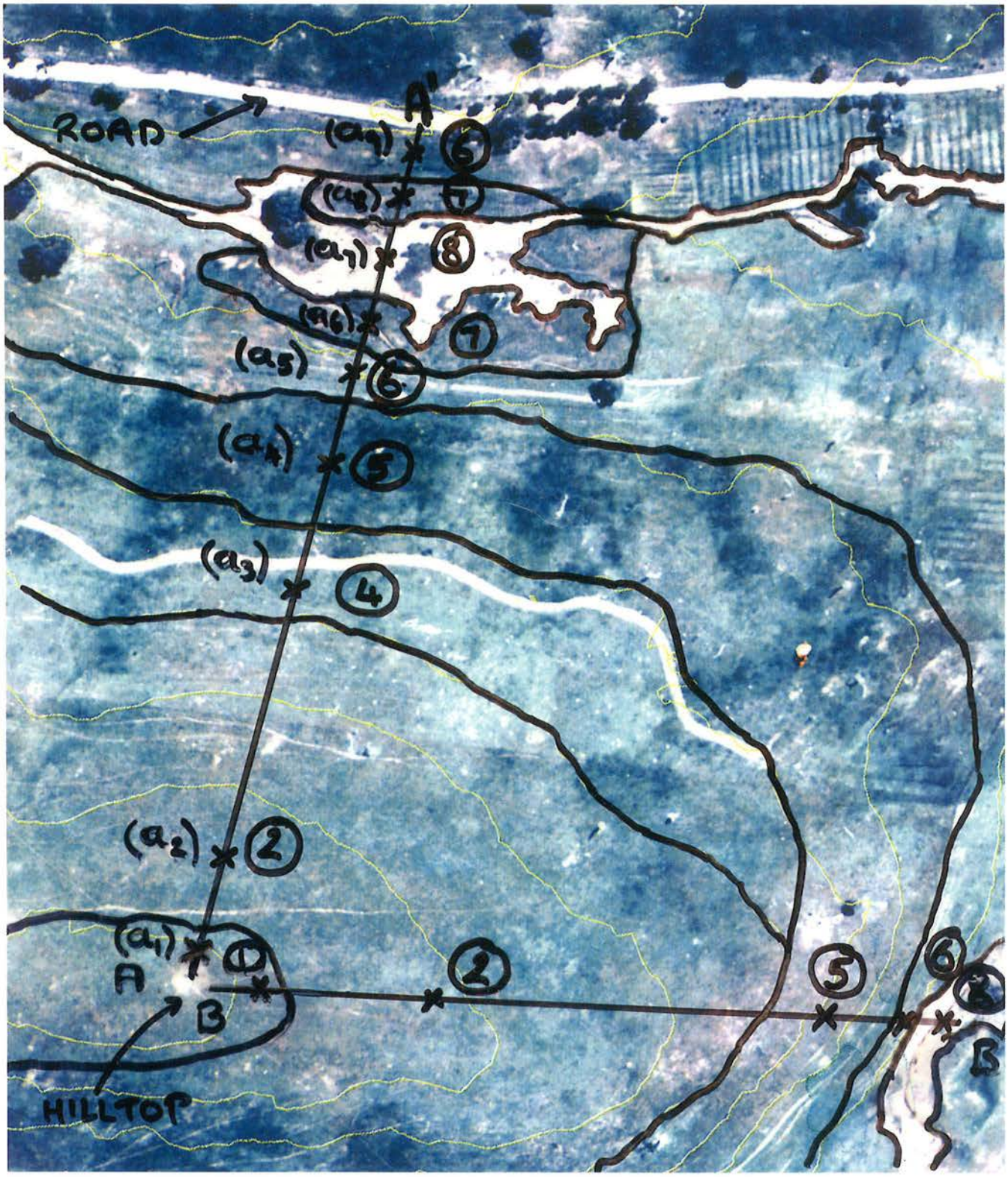


Figure 5a Plastic overlay with soil descriptions set over the aerial photograph

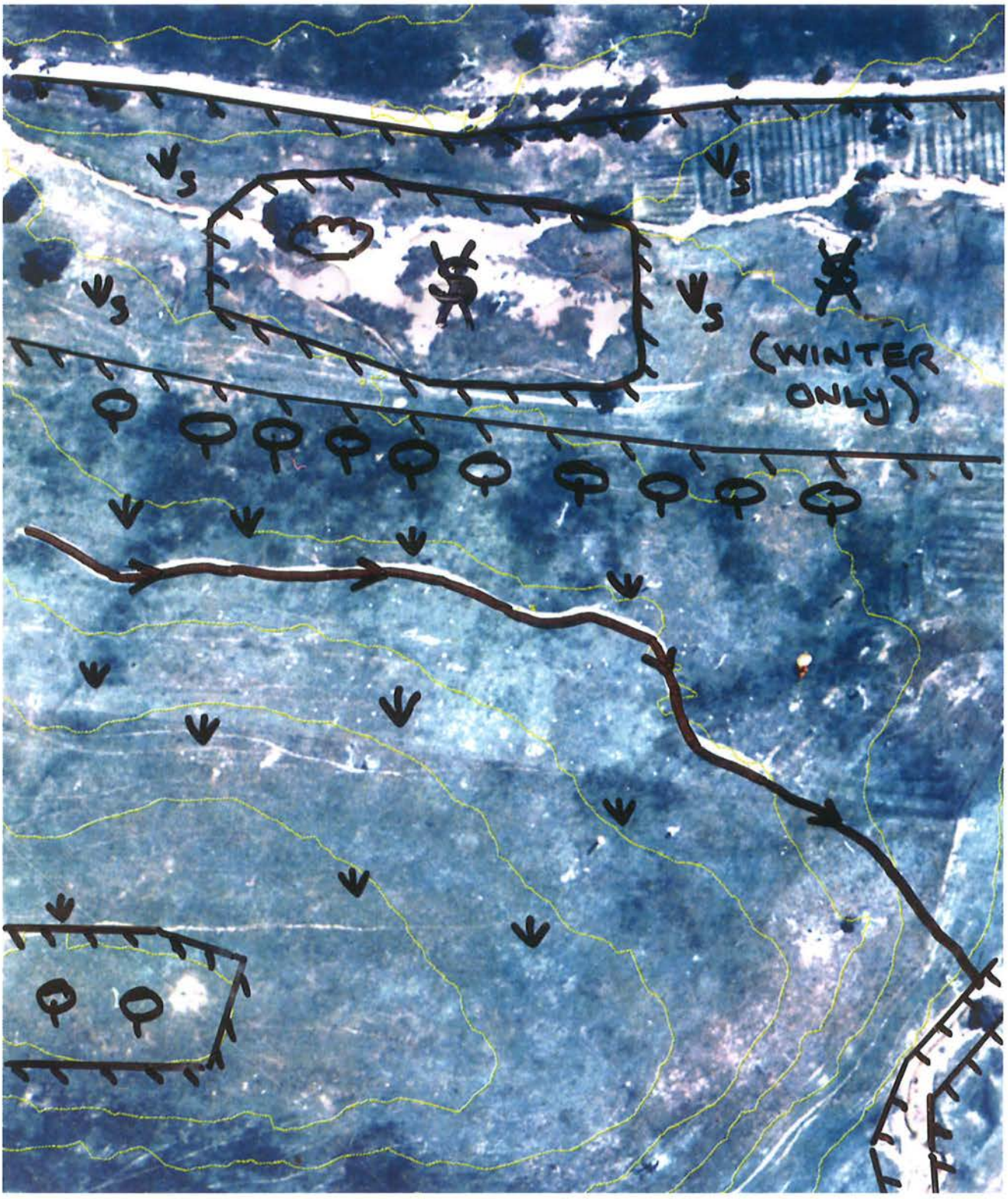


Figure 5b Second plastic overlay with management options added

Using the key for property management planning

The key can be used on its own to help solve a particular problem in a paddock, but is even more useful as an addition to developing a property management plan.

Property management planning means using land according to its capability and identifying land class units is a first step.

Each land classification commonly covers several soil types and is managed in a similar way. However, some soil types within a classification require different management, and so need to be identified by this key. For example, sodic soils need to be identified so that any drains required are not located in this soil type, but higher up the slope because sodic soils are prone to dispersion and erosion.

The overlays such as in Figures 5a and 5b can now be used to identify land classes and management options, as part of a whole farm property management planning program.

Mr Bruce Munday, chair of the Northern Hills Soil Conservation Board, discussing problems of waterlogging and salinity in a local catchment.

Want further information:

- **Guidelines to management of land in the Central Hills Soil Conservation District.**
  District Plan of the Central Hills Soil Conservation Board,
  Primary Industries SA, Sustainable Resources Group, *Soil & Water Environs, Waite Institute, Glen Osmond, 1996.*

- **A guide to better land management.**
  District Plan of the Southern Hills Soil Conservation Board,
  Primary Industries SA, Sustainable Resources Group,
  Soil & Water Environs, Waite Insitute, Glen Osmond, 1996.

- **Guidelines for land management.**
  District Plan of the Northern Hills Soil Conservation Board
  Primary Industries SA, Sustainable Resources Group,
  Soil & Water Environs, Waite Institute, Glen Osmond, 1996.

- **A Land Class Approach to Dryland Salinity Management.**
  A.J. Solomon and C.J. Henschke (in press),
  Primary Industries SA, Sustainable Resources Group,
  Soil and Water Environs, Waite Institute Glen Osmond.

- **Permanent pastures for the Mt Lofty Ranges and Kangaroo Island.**
  T. Prance and P. Fairbrother, Primary Industries SA Fact Sheet (in press).

- **A soil-diagnostic key to manage saline and waterlogged catchments in the Mt Lofty Ranges, South Australia.**
  R. Fitzpatrick, J. Cox, E. Fritsch and I. Hollingsworth.
  Journal of Soil & Use and Management (1994) Vol.10, pp 145-152.

- **Farm trees for the Mt Lofty Ranges - A regional agro forestry handbook.**
  P. Bulman, Primary Industries SA,
  Sustainable Resources Group, *Soil & Water Environs, Waite Institute Glen Osmond, 1995.*

Glossary

Acid soil
A soil with a low pH and in which plant growth may be restricted because of one or more nutritional disorders.

Agroforestry
Managing trees, shrubs and groundcovers to improve farm profitability while protecting and enhancing natural resources. An agroforest for wood production may be in the form of a woodlot, a timberbelt or a wide -spaced agroforest.

Alley farming
Strips of crops or pastures in between belts of fodder shrubs with or without trees.

Catchment
The specified area from which runoff water flows into a stream/streams or basin.

Control structure
A physical structure such as a weir to alter water flow in a stream, to minimise erosive scouring of the stream channel.

Deci - Siemens
See Electrical Conductivity

Dispersion
Breaking up of soil particles into individual clay, silt and sand grains.

Dissolved organic carbon
Organic material which when present gives water a slightly brownish colour. Can cause problems if in excessive concentrations.

Electrical conductivity or EC
A measure of the ability of a material to conduct electric current, due to the concentration of salts in solution. It is measured in deciSiemens/metre or dS/m.

Groundwater
That part of the subsurface water in zones that are saturated with water under pressure equal to or greater than atmospheric pressure.

Gypsum
Calcium sulphate used to reduce dispersion. A naturally mined substance also formed as a by-product of fertiliser manufacture.

Hydrogeology
The study of the occurrence, distribution and movement of water over, on and under the land surface, taking into account the naturally occurring geological formations.

Interceptor drains
A surface or subsurface drain or a combination of both, designed and installed to intercept flowing water.

Land capability
The extent to which land can meet the needs of one or more uses. Land capability classes are often identified which contain land with similar capabilities.

Lime
Calcium carbonate used to neutralise acidic conditions. Often called agricultural or calcitic lime to distinguish it from dolomitic lime, which also contains magnesium carbonate.

Mottling
Soil irregularly marked with spots of colour.

pH
A scale from 1-14 measuring acidity or alkalinity. Below 7 is acid, and above 7 is alkaline. The measurement is usually made in water, or alternatively in calcium chloride which gives readings up to 1.5 units lower.

Property management planning
A whole farm approach to the management of physical, financial, and social resources.

Recharge
The process by which water flows from the soil surface to the groundwater system.

Saline soil
A soil containing sufficient soluble salts to adversely affect the growth of most crop plants.

Sodic soil
A soil with an excess of sodium causing clay dispersion to occur.

Soil consistence
The degree of cohesion or adhesion within the soil mass, or its resistance to deformation or rupture.

Sulphidic soil
A soil that generates sulphuric acid that may leak into drainage systems.

Topography
The general configuration of a land surface, including its relief and the position of its natural and man-made features.

Tunnel erosion
The removal of soil material through subsurface channels developed by seepage water.

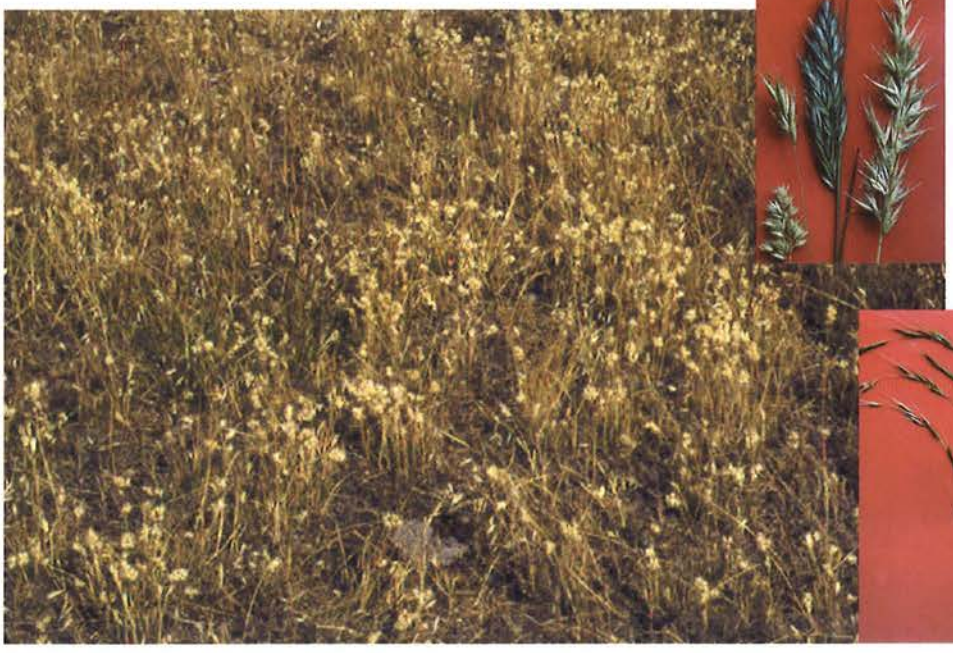
Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Before making any soil observations, look at the plants present, as they may indicate problems. Match them up with the photographs below.

Situation: Well drained

Improved perennial pasture

Native pasture grasses - these could include:



Wallaby grass

Weeping rice grass

Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Situation: Moderately waterlogged and low salt tolerant plants

Rye-grass dominant pasture

Strawberry clover

Toad rush

Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Situation:
Moderately waterlogged and low salt tolerant plants

Dock

fog grass

Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Situation: Strongly waterlogged and low salt tolerant plants

Cotula

Toad rush

Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Situation: Strongly waterlogged and low salt tolerant plants

Rushes/reeds

Heads look like either of these.

Sea barley grass

Appendix 1: Vegetation that indicates the degree of waterlogged or saline conditions

Situation: Strongly waterlogged and high salt tolerant plants

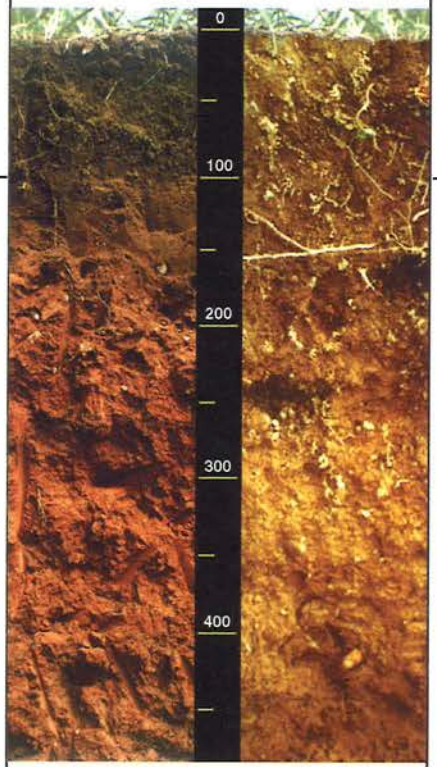
Bare ground

Sea barley grass

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options.

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 1** **Rocky non-arable but mainly with shallow moderately well drained soils** 	Top	Rock outcrops. Plants indicating well-drained conditions. Brown topsoil layer.	**Yes** → →	Infrequent waterlogging	• Fence off area if it s large enough. • Revegetate with local species or refer to 'Farm trees for the Mt Lofty Ranges', P. Bulman, Primary Industries SA, 1995. • Fertilise to improve pasture and spread clover seed. • Lime if pH (water) is less then 5.5
Firm to rigid		Bottom	Red* subsoil layer, usually overlying either hard rock as shown in the photo on this page, or weathered grey rock. *could also be yellow	**No** ↓ ↓		

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options. (continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 2** **Deep well drained red and yellow soils**  	Top	Plants indicate well-drained conditions. Brown topsoil layer.	**Yes** → →	Infrequent waterlogging	• Fertilise existing pasture to improve productivity and water use. • Establish deep-rooted high water use perennial grass and subclover pasture based on cocksfoot and phalaris. Perennial ryegrass is an option above 600mm rainfall and on heavier and more fertile soils. Lucerne is an option on deeper well drained soils which are not too acidic. Slope doesn't always indicate good drainage, check the soil profile. • Encourage existing native grasses on small areas of rock outcrops where establishment may be difficult or uneconomic. • Consider establising scattered trees around rocky outcrops, using local species.
Firm to rigid		Bottom	Red or yellow subsoil layer. (see left and right photos respectively) • May overly red with yellow mottles. • May overly yellow with red mottles (see photo of Soil 2 in the Example Sequence of Soils in Figure 3)	**No** ↓ ↓		

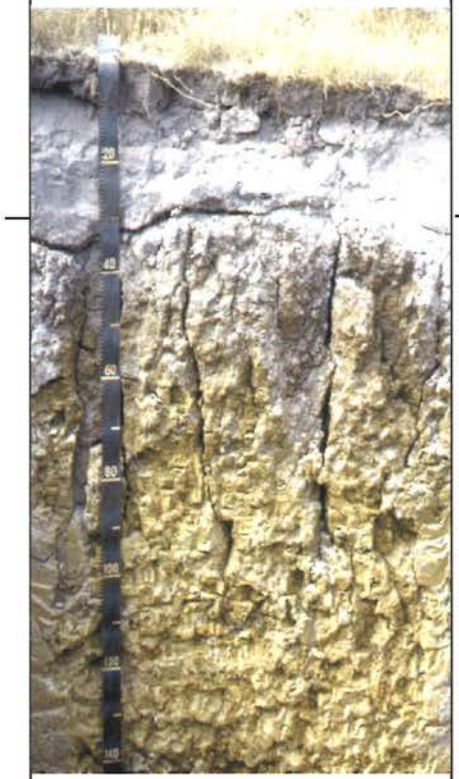
Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options.
(continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 3** **Moderately well drained mottled soils**	Top	Plants indicate well-drained to moderately waterlogged conditions. Brown topsoil layer.	**Yes** → →	Periodic waterlogging	• Fertilise existing pasture to improve productivity and water use. • Establish deep-rooted high water use perennial grass and subclover pasture based on phalaris and fescue. • Include varieties tolerant to waterlogging in the pasture mix. • Cocksfoot is less adapted as it requires very well drained soils. • Consider alley farming or strips of trees on the contour between areas of improved pastures. This will provide windbreaks and/or a fodder reserve for livestock, as well as increasing water use. For species selection, refer to 'Farm trees for the Mt.Lofty Ranges', P Bulman, Primary Industries SA, 1995.
Firm to rigid		Bottom	Red or yellow subsoil layer with yellow or red mottles.	**No** ↓ ↓		

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options. (continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 4** **Poorly drained mottled grey soils** 	Top	Plants indicate strongly waterlogged and low salt conditions. Brown topsoil with grey mottles and red stains. A bleached sub-layer may occur at the bottom of the surface layer. This is because organic matter, iron and clay may have been washed down-slope or into the subsoil.	**Yes** → →	Strongly waterlogged	• Establish deep-rooted high water use perennial grass and subclover pasture, based on phalaris and fescue. Include waterlogging tolerant varieties. • Cocksfoot is not recommended as it requires very well drained soils. • Consider installing interceptor drains, if a perched water table is present. These could discharge into farm dams. • Consider alley farming. • Exclude stock during wet periods. • Note that phalaris may not establish well in acid soils. Liming may be necessary.
Firm to rigid		Bottom	Grey subsoil layer with yellow or red mottles.	**No** ↓ ↓		

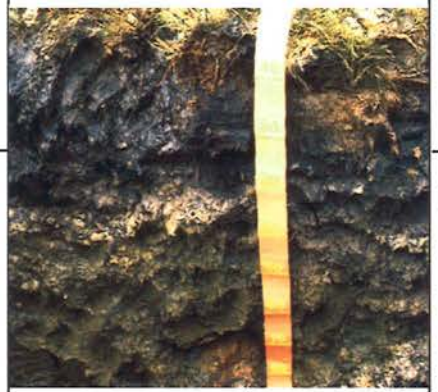
Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options. (continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 5** **Poorly drained grey sodic soil** 	Top	Plants indicate strongly waterlogged and low salt conditions. Grey topsoil with red stains. A bleached sub-layer occurs at the bottom of the surface layer.	**Yes** → →	Strongly waterlogged and sodic	• Establish deep-rooted high water use perennial grass and subclover/strawberry clover pasture. Include water logging tolerant varieties. Phalaris and fescue are best adapted to this situation. Lime if necessary. • Do not install interceptor drains or dams in sodic soils as they can erode and cause any earth structures to fail. • Consider alley farming or agroforestry. • Exclude stock throughout the winter.
Firm to rigid		Bottom	Grey subsoil layer with yellow or red mottles. This layer disperses in water and so is sodic. Take a sample for testing to check. If a sample is saline, this could prevent a soil from dispersing although it is still sodic. An indicator of sodic soil can be vertical cracks and soil columns, such as shown in the photograph on this page, but these are not always seen.	**No** ↓ ↓		

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options. (continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options Soil profiles 6,7 & 8 normally occur as a mosaic and are managed together.
Loose to friable	**SOIL TYPE 6** **Very poorly drained grey saline soil** 	Top	Plants indicate strongly waterlogged and saline conditions. Some additional surface features that indicate salinity are; bare ground, and/or white salt stains when dry, and/or sea barley grass. Grey topsoil with red stains. EC meter reading is more than 0.4 dS/m. A bleached sub-layer occurs at the bottom of the surface layer.	**Yes** → →	Strongly waterlogged and saline	• Fence off area sufficiently up slope from the limit of saline soil. • Plant phalaris, fescue and strawberry clover in less saline areas. Use waterlogging tolerant varieties or • Plant salt tolerant grasses (eg tall fescue, tall wheat grass, Puccinellia) in more saline areas. • Exclude stock completely. • Stabilise eroded areas and gully banks with salt tolerant trees, shrubs and native grasses. • Do no install interceptor drains or dams in saline or potentially saline areas. • Add lime to areas that are strongly acidic. • Where erosion is severe construct simple control weirs or gully head structures to reduce gully gradients.
Firm to rigid		Bottom	Grey subsoil layer with yellow or red mottles. EC meter reading is more than 0.7 dS/m.	**No** ↓ ↓		

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options. (continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 7** **Very poorly drained black saline sulfidic soil** 	Top	Some bare ground with sea barley grass (and some rushes). Other surface features include: - cream salt crystals visible when soil surface is moist (probably gypsum if they have no taste). - white salt crystals visible when soil surface is dry (probably sodium chloride if salty taste). - red iron stains and red gels on the soil surface - black boggy areas with black mottles (smell of rotten egg gas). EC meter reading is more than 0.4 dS/m.	**Yes** → →	Strongly waterlogged, saline and sulfidic	As for Soil Profile 6.
Firm to rigid		Bottom	Grey subsoil layer with yellow or red mottles. EC meter reading is more than 0.7 dS/m.	**No** ↓ ↓		

Appendix 2: Key for identifying surface and soil features that indicate degrees of waterlogged and saline conditions and management options.
(continued)

Consistency (dry soil)	Typical soil photo	Soil layer	Important features		Waterlogging duration	Management options
Loose to friable	**SOIL TYPE 8** **Very poorly drained saline eroded soil** 	Top	Surface features include; - bare eroded areas and gullies. - white salt crystals visible when soil surface is dry (probably sodium chloride if salty taste). EC meter reading is more than 0.4 dS/m.	**Yes** → →	Strongly waterlogged, saline and eroded	As for Soil Profile 6.
Firm to rigid		Bottom	Grey subsoil layer with yellow or red mottles. EC meter reading is more than 0.7 dS/m.			

Appendix 3: Measuring salinity, sodicity (and acidity).

Saline soils contain very high proportions of sodium and chloride, in both the soil solution and on clay particles. Consequently only salt tolerant plants will grow in saline soils.

A convenient way of measuring **salinity** in the soil is to measure the electrical conductivity of a 1:5 soil to water solution with a conductivity meter. The meter must be correctly calibrated according to the manufacturers instructions before use.

Sodic soils contain a higher than desired proportion of sodium on the clay particles. When in contact with water, sodic soils disperse into tiny fragments, which block soil pores on drying. They are difficult to manage, are often hard-setting and susceptible to erosion and waterlogging. Sodicity can be estimated by the degree of cloudiness from a measured sample placed in water.

Dams built in sodic soils can fail due to dispersion in the sub-soil, leading to erosion and tunnelling. Tracks and wheel ruts in sodic soils are also easily eroded.

A saline soil can also be sodic and dispersion is prevented by the concentration of salt. This soil can disperse again once salt is leached out. To accurately identify the area of sodic soil you may wish to send samples from saline areas to a laboratory to test for sodium levels.

Preparing the sample

- Collect soil and crumble to 1 cm pieces or less and remove rocks or plant material. Clods are most easily broken down when the soil is slightly wet.
- Make sure samples are dry before testing as soil moisture can change the results. Air-dry by spreading out the sample on a clean plastic sheet for 2 days.
- Weigh 100g of soil into a clean 600 ml glass jar with a lid, and gently fill with rainwater down the side of the jar, without disturbing the soil at the bottom. This gives a 1:5 ratio of soil to water used for this test. An exact ratio of 1:5 is not essential but it is best to get as close as possible.
- Replace lid and gently invert the jar once. Allow to stand for 4 hours with no vibrations or bumping.

Testing for sodicity

- Determine whether the solution above the sediment at the bottom is; clear or partly cloudy (not sodic), cloudy (medium sodicity), or very cloudy (very sodic), and record this on your field recording sheet. Check the photos in Figure 6 below to help assess sodicity.
- If a sample is highly sodic then you should consider applying gypsum. For recommended rates consult your local agronomic or land management advisor.

Clear or partly cloudy
(not sodic*)

Cloudy
(medium sodicity)

Very cloudy
(very sodic)

(* If saline then could still be sodic)

Figure 6: Visual assessment of sodicity in a 1:5 soil to water suspension

Testing for salinity

- After checking for sodicity, completely stir the whole soil sediment vigorously for 15 seconds and then let stand for a further 15 minutes.
- Measure the electrical conductivity (EC) of the solution in deci-Siemens per metre (dS/m) and record whether your sample is saline or not on the Field Sheet. Sandy or loamy soils (ie the top layer in your profile) are saline if EC is above 0.4 dS/m. Clay soils (ie the bottom layer in your profile) are saline if EC is above 0.7 dS/m.

Testing for acidity

- Acid soils can significantly reduce pasture and livestock production.
- This is an optional test that can be done in the same sample immediately after testing for salinity.
- Measure the soil pH with a calibrated pH meter. Wait a few minutes until you get a stable reading as the measurements may change initially.
- For optimal pasture production, aim to increase soil pH to at least 6.0. See local soils advisor for liming recommendations.

Appendix 4: Interpretation of soil consistence classes

Soil Consistence

Estimating soil consistence can guide us in locating restrictive layers that alter water movement within the soil and landscape, and also the effective root depth for plants. These features can be determined in the field by measuring changes in soil consistence, from loose to rigid, progressively down the soil profile from the soil surface. The classes of soil consistence are described in the adjacent table. The very hard and rigid classes indicate reduced water flow.

Soil texture (eg sand, loam or clay) can also used however, soil consistency is preferred because it can be estimated more easily.

Consistence of a soil material can be estimated in the field by simply manipulating a dry or moist piece of soil in the hand and expressing it as loose, soft, firm, very hard or rigid (see table). Two sets of terms are used to describe consistence, depending on the whether the soil is dry or moist. Alternatively, we can estimate consistence from the difficulty with which soil is excavated, using hand or power equipment, or by general observations of plant growth and water movement in a catchment.

An example of the use of soil consistence is shown in soil type No. 4 (page 28). The 0-0.40m **soft** layer abruptly overlies a **very hard,** heavy clay layer. In the soft layer there is little restriction to water movement and root growth, whereas in the underlying very hard, heavy clay layer, water movement and root growth is severely restricted.

Consistence classes Dry (Moist)	Rupture Resistance on a 30 mm cube of dry or moist soil	Consistence test inferred from excavation difficulty	Environment indication
Loose (Loose)	Block-like piece not obtainable. Only individual sand grains can be picked up between thumb and forefinger	Can be excavated with a spade using arm-applied pressure. Neither application of impact energy nor application of pressure with the foot to a spade is necessary.	No restriction on root growth for annuals and perennials. No restriction on water movement. Periodic soil moisture stress occurs in sands.
Soft (Friable)	Fails (ie crumbles) under slight force applied between thumb and forefinger.	Arm-applied pressure to a spade is insufficient. Excavation can be accomplished quite easily by application of impact energy with spade or by foot pressure to spade.	Root growth of annuals and perennials are not restricted. Slight restriction on water movement; soil water is available to most crops and trees.
Firm (Firm)	Fails under moderate to strong force applied between thumb and forefinger.	Excavation with spade can be accomplished, but with difficulty. Excavation is easily possible with a full length pick using an over-the-head swing.	Water flow is mildly restricted contributing to periodic waterlogging.
Very hard (Very firm)	Does not fail between thumb and forefinger but can be by applying full body weight under foot.	Excavation with a full length pick using an over-the-head swing is moderately to markedly difficult. Excavation is possible in a reasonable period of time with a backhoe mounted on a 40-60KW (50-80hp) tractor.	Root growth of most species is restricted. Water flow is restricted contributing to waterlogging.
Rigid (Rigid)	Does not fail by blow with hammer.	Excavation is impossible with a full length pick using an over-the-head arm swing or with reasonable time period with a backhoe mounted on a 40-60KW (50-80hp) tractor.	Root growth of most species is severely restricted. Water flow is strongly restricted contributing to waterlogging.