Soil and land attribute data descriptions

Soil landscape map unit spatial data framework
for southern South Australia

The Department of Environment, Water and Natural Resources (DEWNR) Soil and Land Program has produced 41 standard Soil and Land Attribute Datasets that describe important features for sustainable land management and agricultural productivity. This document gives a summary of each attribute dataset and how to interpret map legend categories and analysis data classes.

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INTRODUCTION

What are soil and land attributes?

Soil and land attributes are inherent soil and land surface features that affect plant growth, land use, land management and agricultural productivity. In addition, soil and land attributes are strongly linked to ecosystem services such as providing:

a) protection from erosion
b) maintenance of catchment health (i.e. influencing sediment and nutrient retention and release from the landscape)
c) filtering and cleaning of subsurface water flows
d) recharge to groundwater
e) resilience to climate variability (owing to moisture-holding properties which dictate when rainfall is actually available to plants).

These datasets embody interpreted information and knowledge from land resource assessment experts, and are designed to highlight key issues, limitations, opportunities, and potential off-site impacts that can arise from people's use and management of the land.

Mapping of soil and land attributes provides a spatial tool to focus attention, and inform where to plan and prioritise activities to address important regional land management issues. Single attribute maps have been produced so that specific issues can be easily assessed. (Other products are available that consider many soil attributes in combination, for example in land use potential modelling).

Spatial data statistics provide a complementary set of information, to summarise how much of an issue (at different levels of severity) is present in each area of interest. **It is important for users to recognise that 'Mapping Data' has been simplified for display purposes, while *spatial data statistics* rely on more detailed information ('Analysis Data').**

The distinction between Analysis Data and Mapping Data is discussed further below.

Potential applications for this data include:

a) targeting on-ground works for improvement of land, water and vegetation condition
b) development of land management guidelines
c) monitoring land condition
d) land use planning
e) input to spatial biophysical modelling (e.g. crop suitability, landscape-scale water quantity and quality, groundwater recharge, etc.).

How was the mapping undertaken?

Mapping of soil and land attributes was undertaken across the agricultural zone of South Australia (southern SA) via the State Soil and Land Mapping Program (1990–2001). The scale and coverage of mapping was based on 1:100,000 scale, with finer resolution mapping (1:50,000) available in higher rainfall and more intensively-used areas.

As the diversity of soils and landscapes typically cannot be displayed at these mapping scales, the surveyors developed a system capable of presenting the key issues, and capturing comprehensive underlying detail that could be accessed as needed.

The main steps undertaken were:

1. *Developing standardised assessment methods*

   An assessment scheme was developed for each attribute. This is described further in *Assessing Agricultural Land* (Maschmedt 2002), and had classes ranging from 1 up to a value of 8, as a means to highlight increasing limitation or susceptibility to degradation issues. Class 1 land represents no limitation with respect to the particular attribute, while the higher classes indicate more limiting or severe conditions. Assessments were based on the integration of field observations, laboratory analyses, understanding of regional landscape processes and stratigraphy, other existing mapping data, and expert judgement to extrapolate from limited data.

2. *Defining particular soil and landscape elements*

   Field surveyors visualised the landscape in distinct elements (or components) based on recognisable features —for example dunes, swales, rises—in order to make separate assessments on each component of the landscape.

3. *Assigning spatial boundaries or map units*

   According to a predefined mapping scale (either 1:50,000 or 1:100,000), *Soil landscape map units* were drawn onto aerial photos, and subsequently digitised into a GIS coverage. These map units often enveloped a number of landscape components with a limited range of associated soils.

4. *Capturing underlying complexity in linked data tables*

   Landscape components (and associated soils) often could not be spatially defined within the enveloping map unit. Data tables, linked to each map unit, were used to capture the attribute assessments for each landscape component. These record an area proportion estimate (for the map unit) of the spatial extent of each attribute class. Data were originally recorded against each landscape component, but this is now presented as a sum total for each attribute class at the map unit level. This is referred to as 'Analysis Data' (see Figure 1 and example below).

5. *Developing simplified mapping categories*

   To help communicate key issues, a set of rules (one rule for each attribute) were developed to convert underlying tabulated information into a mapping class (or map legend category) capable of presenting a useful summary of the underlying data.

Further information is available from:

- *The soils of southern South Australia* (Hall et al. 2009) – Part 1 and Part 2
- *Assessing Agricultural Land* (Maschmedt 2002)
- View the data on NatureMaps (>Soils)

What is the difference between Analysis Data and Mapping Data?

These concepts are illustrated below using an example view from NatureMaps. Figure 1 shows the attribute *Salinity – watertable induced* where the Identify Tool (from the Tools menu) has been used to view detailed information for the *Soil landscape map unit* labelled *LMAZHC* (highlighted in yellow). For this particular map unit:

- ***Mapping Data*** – refers to the assigned map legend category (in red below):

Map legend category	E: Moderately high to high, or 30 - 50% highly saline

Map legend categories (and hence Mapping Data) represent a summarised or simplified description of the map unit contents. The definition and assignment of map legend categories depend on custom pre-determined rules that vary for each attribute. Rules have been designed to convey practical summary information and/or highlight features of interest. For some attributes they aim to describe the levels of heterogeneity present within a single map unit.

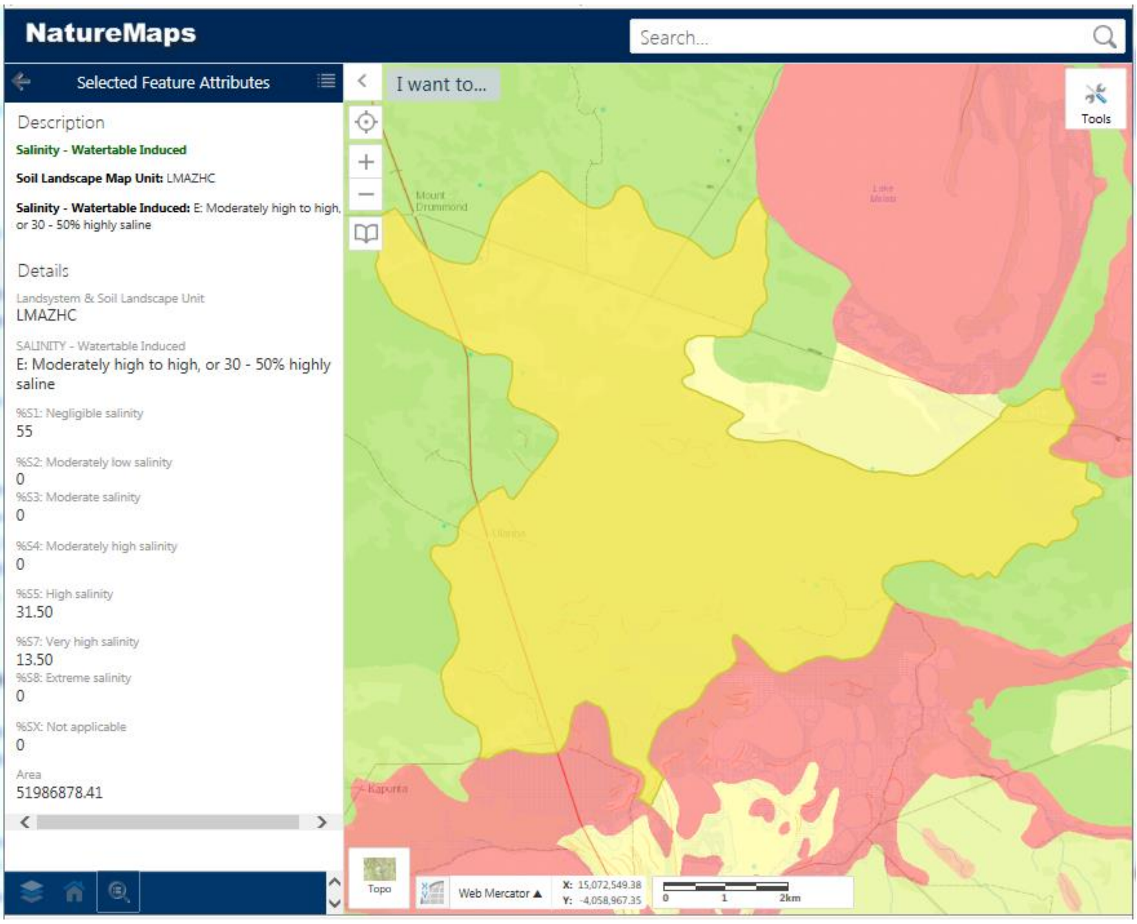

Figure 1. Example query from NatureMaps illustrating Mapping Data (i.e. map class E is shown in this case) and Analysis Data (i.e. area percentage estimates for attribute classes S1–SX).

Note: the two decimal places in the Analysis Data should not be interpreted as a level of precision. This is due to an automated area proportion calculation applied to original semi-quantitative field observations, i.e. where landscape components were originally recorded as combinations of dominant (>50%), very extensive (>60%), extensive (30 - 60%), common (20 - 30%), limited (10 - 20%), or minor (<10%).

Mapping Data classes can, for example, reflect the area-weighted average attribute value, the most common attribute, the most severe rating above a certain threshold, or the area proportion of certain levels of attribute severity. In some cases, up to 70% of available information within a map unit may be left undescribed in the Mapping

Data due to this simplification process. For example, the most common soil type may sometimes account for as little as 30% of a map unit.

Mapping Data should <u>not</u> be used to calculate summary *spatial data statistics* for areas associated with different attribute classes (or levels of severity/limitation).

- ***Analysis Data*** – refers to the estimated area proportions corresponding to each attribute class (highlighted in blue below):

Attribute Class	S1	S2	S3	S4	S5	S7	S8	SX
Description	Negligible salinity	Moderately low salinity	Moderate salinity	Moderately high salinity	High salinity	Very high salinity	Extreme	Not applicable
Analysis Data	55	0	0	0	31.5	13.5	0	0

Analysis Data <u>should</u> be used to calculate summary *spatial data statistics*.

Area proportions of each attribute class, multiplied by the map unit area, can be used to tally up the total areas corresponding to different levels of attribute severity/limitation.

For example, across the entire southern SA soil mapping area, summary *data statistics* for *Salinity – watertable Induced* can be tallied as follows:

Attribute Class	Area (ha)	Description	Indicators
S1	13,610,276	Negligible salinity	No evidence of salt effects
S2	927,594	Moderately low salinity	Deep rooted horticultural species and pasture legumes affected
S3	355,543	Moderate salinity	Many field crops and lucerne affected. Halophytes usually evident
S4	162,360	Moderately high salinity	Too salty for most field crops and lucerne. Halophytes common
S5	196,637	High salinity	Land dominated by halophytes with bare areas. Puccinellia and tall wheat grass thrive
S7	188,010	Very high salinity	Land is too salty for productive plants - supports only hardy halophytes
S8	108,900	Extreme	Bare surface, may be salt encrusted
SX	216,139	Not applicable	
TOTAL	15,765,459		

Important considerations

The following general principles need to be borne in mind when using the soil and land attribute maps:

1. The information is derived from limited field inspection, and is subject change without notice

DEWNR Soil and Land Program will consider any feedback, comments, suggestions or data which can be used to improve the accuracy and utility of this mapping.

2. Boundaries between mapping units should be treated as transition zones

Soil landscape map unit boundaries are typically not as sharp as lines on maps imply. Changes may occur imperceptibly over a distance of a kilometre or more, so changes from one legend category to another can be assumed to be gradual.

3. The maps are intended to provide a regional overview and should not be used to draw conclusions about conditions at specific locations

Soil and land attribute maps entail a significant level of generalisation. Commonly, a specified attribute class may apply to only 50% or less of a *Soil landscape map unit*. Analysis Data, and associated spatial data statistics, can account for heterogeneity within map units – however simplified Mapping Data with generalised legend categories cannot depict spatial features at a paddock-scale. This is acceptable in a regional, subregional or catchment-level context where maps are only intended to provide a visualisation of where particular conditions are likely to occur. At best, the mapping can be used to provide an overview of property-level conditions. Zooming in on specific areas and treating map units as homogeneous entities will be misleading. For site specific information, there is no substitute to on-site inspection.

4. The scale of maps should not be enlarged beyond their scale of publication

Mapping information is presented at a scale which reflects its reliability. Information presented at say 1:100,000 scale, is based on relatively low density ground-truthing and is for regional, sub-regional and catchment-level applications only. Enlargement of a 1:100,000 scale map to 1:20,000 for example, is a simple process, but generates a product in which the level of apparent precision cannot be justified by the level of data used to compile it.

5. Independent expert advice should be sought prior to using this information for commercial decision-making

The production of soil and land attribute maps involves a considerable degree of interpretation of a range of data by land resource assessment specialists. Although every effort is made to document the processes underpinning these interpretations, there may be some situations in which a particular use of the information has not been considered. It is therefore essential that independent expert advice be sought before making any significant decisions based on this attribute information.

6. To avoid inconsistencies and confusion any updates to this soil attribute mapping are to be managed by the DEWNR Soil and Land Program

To maintain consistency of the dataset in the future, it is essential that all updates are managed by the DEWNR Soil and Land Program.

SOIL CHEMISTRY ATTRIBUTES

Acidity

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Soil acidity varies across the landscape, with management practices having a greater influence than soil type within a climatic zone. However, there are broad trends across landscapes, so the *Acidity* assessment is intended to highlight land where acidity is or could become a significant problem.

Assessments are based on an interpretation of *Soil landscape map units*. Acidity varies within soil acidity attribute classes (depending on management practice and climate), and within mapping units (which often include a complex of soils). Classifications are made according to pH measurements and extrapolation between similar environments. All land which is inherently susceptible to acidity is classified accordingly, regardless of land use or management.

Soil landscape map units are categorised into legend categories according to the most acidic component, provided that it accounts for more than 30% of the area of the map unit. Limited occurrences of acidic soils (i.e. account for 10–30% of the area of the map unit) are indicated as an additional category.

The assessment combines three elements of soil acidity:

– Three levels of severity are used, viz. non-acidic, acidic and strongly acidic.
– Because acidity can change markedly from topsoil to subsoil, a profile trend is included in the assessment.
– Soils with low clay/low organic matter content are more susceptible to acidification than other soils, and are described as having a low buffering capacity (i.e. low capacity to resist acidification). In the assessment, low buffering capacity soils are separated from those with moderate to high buffering capacity.

Attribute Class	* pH of topsoil (0–10 cm)	* pH of subsoil (30–80 cm)
H1_1	Neutral or alkaline	Alkaline
H1_2		Neutral
H1_3,1_4		Acidic
H2_1	Acidic, moderate to high buffering capacity	Alkaline
H2_2		Neutral
H2_3		Acidic
H2_4		Strongly acidic
H3_1	Acidic, low buffering capacity	Alkaline
H3_2		Neutral
H3_3		Acidic
H3_4		Strongly acidic
H4_2	Strongly acidic, moderate to high buffering capacity	Neutral
H4_3		Acidic
H4_4		Strongly acidic
H5_3	Strongly acidic, low buffering capacity	Acidic
H5_4		Strongly acidic
HX	Not applicable	

* Strongly acidic	pH_{CaCl2} <4.5	pH_{H2O} <5.5
Acidic	pH_{CaCl2} 4.5–5.4	pH_{H2O} 5.5–6.4
Neutral	pH_{CaCl2} 5.5–6.9	pH_{H2O} 6.5–7.9
Alkaline	pH_{CaCl2} $\geq$7.0	pH_{H2O} $\geq$8.0

Legend categories account for surface and subsoil acidity, and surface buffering capacity (i.e. capacity of surface soil to resist acidification).

Legend Category	Soil acidity	Surface buffering capacity
A	Negligible	Any
B *	10–30% of soils acidic	Any
C	Surface soil only	Moderate to high
D	Surface soil only	Low
E	Surface and subsoil	Moderate to high
F	Surface and subsoil	Low
X	Not applicable	

* Includes any susceptible soils, without distinction between surface and subsoil or buffering capacity.

Acid sulfate soil potential

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Soils or sediments with accumulations of iron sulfides in the upper layers under waterlogged or highly reducing (anaerobic) conditions are termed sulfidic. So long as these materials remain waterlogged or de-oxygenated, they are innocuous and do not cause problems. Drainage or other disturbance which causes oxidation creates a chain of events resulting in the release of highly acidic leachates from the soil. The material is then described as acid sulfate soil.

Specialised analyses can be done to confirm the presence of sulfidic materials (i.e. those with potential to develop acid sulfate conditions). Observations of significant decline in pH as the sample dries also provide strong evidence. As a general rule, any land with a shallow watertable and a source of sulfate (e.g. gypsum or pyrite minerals) is at risk.

The assessment procedure for identifying sulfidic soils is as follows:
At least the lower part of the soil profile must be saturated for most of the year:
AND land lies within a geological formation containing pyrite bands
OR near surface watertables are highly saline (more than 10,000 mg/kg dissolved salts)
OR there are gypsum deposits in the landscape (e.g. lunettes around salt lakes or salt pans, or gypseous hummocks)
OR gypsum segregations (crystals or soft flakes) occur in the soil profile.

This assessment is therefore based on observable morphological properties. Assessments of *Soil landscape map units* are made according to whether the major part is at risk, risk is confined to localised areas, or there is no risk. The overall proportion of the *Soil landscape map unit* which is at risk is then determined.

Attribute Class	Potential for development of acid sulfate soil
J1	Negligible
J4	Potential for localised (patchy) development
J5	Potential for more than 50% of land to be affected
J0	Incomplete data (usually wet inland areas)
JX	Not applicable

Soil landscape map units are categorised into five legend categories depending on the proportion of land susceptible to acid sulfate potential. An extra category covers inland wet areas where knowledge is incomplete regarding the potential for acid sulfate soil development after draining.

Legend Category	Proportion of land susceptible to the development of acid sulfate soils
A	Negligible
B	1–10%
C	10–30%
D	30–60%
E	More than 60%
O	Incomplete data (usually wet inland areas)
X	Not applicable

Alkalinity

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Alkalinity is usually an inherent characteristic of soils, although it can be increased by irrigation with alkaline or saline water. Soils made alkaline by calcium carbonate alone rarely have pH_{water} values above 8.3. Alkaline soils with pH values higher than 8.3 usually have significant exchangeable sodium (sodic soils) and carbonates and bicarbonates of sodium along with calcium carbonate. Soils layers containing fine calcium carbonate within the soil matrix are termed 'calcareous'. Extensive observations indicate that cereal root growth is very poor or non-existent in soils (particularly clayey soils) with pH_{water} values exceeding 9.2. Alkaline soils are largely (but not exclusively) confined to areas with less than 400 mm annual rainfall.

The alkalinity of the surface and subsoil of each *Soil landscape map unit* is assessed according to soil pH profiles, and by extrapolation between similar soil materials:

Non alkaline soils have pH_{water} of less than 8.0
Alkaline soils have pH_{water} of 8.0–9.2
Strongly alkaline soils have pH_{water} of more than 9.2

Attribute Class	pH of surface (0–10 cm)	pH of subsoil (30–80 cm)
I1_1	Non alkaline	Non alkaline
I1_2	Non alkaline	Alkaline
I1_3	Non alkaline	Strongly alkaline
I2_2	Alkaline	Alkaline
I2_3	Alkaline	Strongly alkaline
I3_3	Strongly alkaline (10–30 cm)	Strongly alkaline
I4_3	Strongly alkaline (0–10 cm)	Strongly alkaline
IX	Not applicable	

Soil landscape map units are categorised according to the most alkaline proportion of the map unit, provided that it accounts for more than 30% of the area. Limited occurrences of alkaline surface soils (i.e. account for 10–30% of the area of the map unit) are indicated as an additional category.

Legend Category	Surface (0–10 cm)	pH of subsoil (30–80 cm)
A	Non alkaline	Non alkaline
B	Non alkaline	Alkaline
C	Non alkaline	Strongly alkaline
D	10–30% alkaline	Any
E	Alkaline	Alkaline
F	Alkaline	Strongly alkaline
G	Strongly alkaline (10–30 cm)	Strongly alkaline
H	Strongly alkaline (0–10 cm)	Strongly alkaline
X	Not applicable	

Aluminium toxicity

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Many plants are sensitive to aluminium at even small concentrations. Aluminium occurs in most soils, but its availability to plants is highly pH dependent. Although there is some evidence to suggest that aluminium availability increases in strongly alkaline soils, most aluminium toxicity is reported in strongly acidic soils. As a general rule, correction of soil acidity will alleviate aluminium toxicity symptoms.

Plants vary in their susceptibility to aluminium toxicity, so the three attribute classes used in the assessment of aluminium toxicity are based on critical levels for aluminium sensitive plants such as lucerne.

The potential aluminium toxicity of the soils occurring within a *Soil landscape map unit* is estimated from limited laboratory analyses and extensive extrapolation according to similarity of soil type. Toxicity can vary significantly within a *Soil landscape map unit*.

Attribute Class	Aluminium toxicity: Degree of limitation	0.01 M $CaCl_2$ extractable aluminium
TAL1	Low	<2 mg/kg
TAL2	Moderate	2–4 mg/kg
TAL3	High	>4 mg/kg

Each map unit is categorised into legend categories according to various proportions of high and moderate toxicity. Because aluminium toxicity is so highly pH dependent, and pH in turn is highly management dependent, the mapped legend categories are very generalised.

Legend Category	Proportion of land with potentially high or moderate aluminium toxicity
A	Negligible to minor
B	10–30% moderate toxicity
C	30–90% moderate toxicity
D	30–90% moderate and up to 30% high toxicity
E	More than 90% moderately toxicity
F	30–90% high toxicity
G	More than 90% high toxicity
X	Not applicable

Boron toxicity

Boron salts occur naturally in most soils and is an essential trace element, but at higher concentrations, it is toxic to many agricultural plants. High concentrations of boron tend to occur where marine sediments (which are high in boron) have influenced soil formation. Because boron salts are slightly soluble, they are leached out of the rootzone in higher rainfall areas, but in lower rainfall areas, or on land where impermeable clay layers at depth prevent leaching, boron concentrations can be high. Work by CSIRO has established that concentrations of more than 15 mg/kg are toxic to cereals, and other work suggests that the tolerance of horticultural crops is significantly lower. Toxic effects are more marked in dry seasons when roots penetrate deeper into the soil. Excess boron cannot be removed from soil or treated in any way under dryland farming conditions. Accidental or deliberate breeding for boron tolerance has produced a range of cultivars which are appropriate for affected soils. This land assessment is intended to highlight areas where boron toxicity may affect plant growth, at least in some seasons.

Assessments are made from soil test results and extrapolation between similar soil materials and environments. Each *Soil landscape map unit* is assessed according to the average estimated depth to toxic boron concentration.

Boron toxicity (depth to toxic layer)

Legend categories are determined by rating the most severely affected landscape proportion, provided it occupies at least 30% of the area of the *Soil landscape map unit*.

Attribute Class	Legend Category	Depth to boron concentrations exceeding 15 mg/kg
TB1	A	None present or deeper than 100 cm
TB2	B	50–100 cm
TB3	C	25–50 cm
TB4	D	10–25 cm
TB5	E	Less than 10 cm
TBX	X	Not applicable

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Boron toxicity (proportion of land affected)

Legend categories are based on the proportion of the *Soil landscape map unit* with boron concentrations exceeding 15 mg/kg in the upper 100 cm of the soil.

Attribute Class	Land affected by boron toxicity (>15 mg/kg extractable boron shallower than 100 cm)
TB1	Land not affected by boron toxicity
TB2,3,4,5	Land affected by boron toxicity
TBX	Not applicable

Legend Category	Proportion of land with boron toxicity in the upper 100 cm of soil
A	Negligible
B	1–10%
C	10–30%
D	30–60%
E	More than 60%
X	Not applicable

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Inherent fertility

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There are countless ways in which land could be classified according to some measure of fertility. Most would be more a reflection of management practice than any inherent soil condition, and would be highly variable both spatially and temporally. Using soil inherent fertility attribute classes which incorporate a relative ranking provides a simple (albeit subjective) method of classifying land with respect to fertility. Soils at the extremes of the fertility spectrum (i.e. highly fertile and highly infertile) set the limits of the classification, and all other soils are fitted in between. Five attribute classes are used.

Self-mulching black cracking clays are considered to be representative of South Australia's most fertile soils, while highly leached sands are the least fertile. Each of the 61 *Soils (soil type)* representing the range of soils within SA's agricultural lands is classified relative to these extremes, on a scale of one to five. A full list of these classifications is tabulated in the document *Assessing Agricultural Land* (Maschmedt 2002). Soil properties such as soil texture, exchangeable cation characteristics, leaching capacity, acidification potential, carbonate and ironstone content are used as classification criteria.

Attribute Class	Legend Category	Inherent fertility
N1	A	High to very high
N2	B	Moderate
N3	C	Moderately low
N4	D	Low
N5	E	Very low
NX	X	Not applicable

To account for variations in the inherent fertility of the different soils within a *Soil landscape map unit*, an average score is calculated for each map unit, according to the proportions of different soils. The score is then categorised into one of the five inherent fertility legend categories. Descriptions for attribute classes and legend categories are shared, as shown above.

Sodium toxicity

Many soils in the drier parts of southern Australia have very high levels of deep subsoil sodicity (i.e. exchangeable sodium percentages (ESP) exceeding 25), generally at depths of between 50 and 100 cm, but sometimes shallower. These conditions are invariably associated with high pH, moderate salinity and often high boron concentrations, all of which are natural features of these soils. They are not necessarily associated with poor structure. There is some evidence to suggest that these high levels of sodicity are toxic to some plants, particularly horticultural species. If there are toxic effects, it is reasonable to assume that in some years at least, the sodicity is preventing optimum water use efficiency, and could therefore be contributing to rising watertables and reduced crop yields. In practice, neither gypsum nor any other ameliorant will have any significant effect on these soils, due to the very high rates required and the difficulty of application. The use of plants with sodium tolerance is one solution. This implies cultivar selection focussed on sodium tolerance (parallel to the boron situation), or the use of naturally occurring plants with sodium tolerance.

Estimates of ESP are based on extrapolation of laboratory analyses between similar soil materials and soil types. Each *Soil landscape map unit* is assessed according to the estimated depth to toxic sodium concentration.

Sodium toxicity (depth to toxic layer)

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Legend categories are determined by rating the most severely affected landscape component, provided it occupies at least 30% of the area of the *Soil landscape map unit*.

Attribute Class	Legend Category	Depth to ESP exceeding 25
TNA1	A	None present or deeper than 100 cm
TNA2	B	50–100 cm
TNA3	C	25–50 cm
TNA4	D	10–25 cm
TNA5	E	Less than 10 cm
TNAX	X	Not applicable

Sodium toxicity (proportion of land affected)

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Attribute Class	Area affected by sodium toxicity (Exchangeable Sodium Percentage >25 shallower than 100 cm)
TNA1	Land not affected by sodium toxicity
TNA2,3,4,5	Land affected by sodium toxicity
TNAX	Not applicable

Legend categories are based the proportion of the *Soil landscape map unit* with exchangeable sodium percentages (ESP) of more than 25 in the upper 100 cm of the soil.

Legend Category	Proportion of land with sodium toxicity in the upper 100 cm of soil
A	Negligible
B	1–10%
C	10–30%
D	30–60%
E	More than 60%
X	Not applicable

Surface and subsoil carbonates

Soils containing carbonates of calcium, and to a lesser extent magnesium, are widespread across South Australia's agricultural districts, particularly in the less than 400 mm rainfall zone. They can occur as finely divided segregations intimately mixed with the sand and clay particles of the soil, as hard nodules or concretions (commonly called rubble), or as sheet rock or calcareous hardpan (commonly called calcrete). Fine carbonates reduce the availability of several nutrients, restrict the performance of a range of crops and pastures, and retard the breakdown of some herbicides. These effects are amplified at higher carbonate concentrations (i.e. in very highly calcareous soils). Hard carbonates reduce available waterholding capacity, and in the case of calcrete, limit rootzone depth.

The nature, depth to and concentration of carbonates are routinely assessed during field mapping work. Presence of carbonates is determined by the application of 1 M HCl. The strength of any effervescence is recorded as follows:

Reaction to 1 M HCl	Category
No audible or visible effervescence	Non calcareous
No visible, but audible effervescence	Slightly calcareous
Audible and slightly visible effervescence	Moderately calcareous
Moderate visible effervescence	Highly calcareous
Strong visible effervescence (bubbles 'jump up')	Very highly calcareous

These parameters can be readily assigned to *Soil landscape map units*, although variations between soil types within landscapes mean that values refer to the most common condition. In the surface and subsoil carbonate assessments, the three intermediate categories (viz. 'slightly', 'moderately' and 'highly calcareous') are combined. Very highly calcareous soils are separated because of their significant impact on nutrient availability, root growth and pesticide breakdown.

Surface carbonate

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Attribute Class	Surface soil reaction to 1 M HCl
KA1	No reaction – non calcareous
KA2	Slight to moderate reaction – slightly to highly calcareous
KA3	Strong reaction – very highly calcareous
KAX	Not applicable

Soil landscape map units are categorised into legend categories according to the proportion of the area with calcareous surface soils (i.e. fine carbonate in the soil matrix). Where more than 30% of surface soils are calcareous, there is a further subdivision to highlight those areas where very highly calcareous surfaces are predominant.

Legend Category	Proportion of land with calcareous surface soils
A	Negligible
B	Up to 10%
C	10–30%
D	30–60%, mainly moderate to highly calcareous soils
E	30–60%, mainly very highly calcareous soils
F	More than 60%, mainly moderate to highly calcareous soils
G	More than 60%, mainly very highly calcareous soils
X	Not applicable

Subsoil carbonate

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[State map]
[Spatial data]
[Metadata]

Attribute Class	Depth to very highly calcareous material (strong reaction to 1 M HCl)
KB1	More than 60 cm
KB2	30–60 cm
KB3	Less than 30 cm
KBX	Not applicable

Depth to highly calcareous subsoils (i.e. fine carbonate in the soil matrix) may vary significantly across the landscape. Each *Soil landscape map unit* is categorised into legend categories according to the proportion of its area with highly calcareous subsoils within 30 cm of the surface. A further subdivision is made to highlight land where highly calcareous subsoils occur within 60 cm of the surface.

Legend Category	Proportion of land with highly calcareous subsoils within 60 cm of surface
A	Negligible
B	Up to 30% (30–60 cm)
C	More than 30% (30–60 cm)
D	Up to 30% shallower than 30 cm, and up to 30% at depths of 30–60 cm
E	Up to 30% shallower than 30 cm, and more than 30% at depths of 30–60 cm
F	30–60% shallower than 30 cm, and up to 30% at depths of 30–60 cm
G	30–60% shallower than 30 cm, and more than 30% at depths of 30–60 cm
H	More than 60% shallower than 30 cm
X	Not applicable

SOIL EROSION ATTRIBUTES

Gully erosion

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Gully erosion covers all forms of mass erosion occurring in watercourses. The intent is to identify land where gully erosion has occurred in the past or is currently occurring. Frequently it is not possible to map individual watercourses at 1:100,000 or 1:50,000 mapping scales, or to map out eroded sections from non-eroded sections of watercourses. The approach used is to specify the proportion of land within a *Soil landscape map unit* which is or has been affected by erosion.

Attribute Class	Presence of gully erosion
G1	Not affected
G2	Affected
GX	Not applicable

Legend categories have been defined by calculating the proportion of land affected by gully erosion, as below:

Legend Category	Proportion of land affected by gully erosion
A	Negligible
B	Up to 5%
C	5–10%
D	10–20%
E	20–50%
F	More than 50%
X	Not applicable

Mass movement (landslip)

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Mass movement occurs on sloping ground where large slabs of the ground surface separate and slide or flow downhill. The phenomenon is probably the result of loss of binding in the soil mass following clearing of woody vegetation, but is almost certainly triggered by excessive wetness in the soil causing simultaneous loss of strength and increased mass. The potential for mass movement, based on existing occurrences, is closely linked to underlying geology.

Slope is clearly a critical factor influencing mass movement, and virtually any slope steeper than 30% is at risk once cleared. However, some landscapes are more susceptible than others. Three geological/soil associations appear to be prone to damage in the agricultural districts of South Australia:

– Soils on unconsolidated and slowly permeable substrate materials. The clays of the old glacial valleys of Fleurieu Peninsula are in this category. Susceptible soils include deep clays and sand to sandy loam over clay types on slopes as low as 12%.

– Soils on sodic shales and quartzites. The Tapley Hill, Brachina and ABC Range Formations appear to be most susceptible. Mass movement of loam over clay soils on these formations is common in the Barunga Range and the Willunga Escarpment where slopes exceed 20%.

– Soils on strongly laminated shaly bedrock. On slopes where the laminations in the rock are parallel to the ground surface, lubrication of these planes of weakness by water can cause slippage of the overlying soil. Occurrences are widely distributed, although not common, on slopes steeper than 20% in the Mount Lofty Ranges and to a lesser extent in the steeper country of the Northern Agricultural Districts.

Assessment entails the identification of land with potential for movement (based on the criteria outlined above), and delineation of land which is already affected. Assessments are based on an interpretation of *Soil landscape map units*.

Attribute Class	Presence of mass movement
L1	Not affected and negligible potential
L2	Not affected but with potential
L3	Affected
LX	Not applicable

Legend categories have been defined by calculating the proportion of land affected (or with potential for) by mass movement, as below:

Legend Category	Extent of (or potential for) landslip
A	Negligible and no potential
B	Negligible – less than 30% of land with potential
C	Negligible – more than 30% of land with potential
D	Up to 5% of land affected
E	More than 5% of land affected
X	Not applicable

Scalding

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Scalding refers to land where the surface soil has been eroded, exposing sub-surface material which is physically and/or chemically hostile to plant growth. As a consequence, the bare surface is susceptible to further erosion, and may shed sufficient water to cause off-site erosion. Scalding is primarily a condition affecting land in low rainfall environments. This assessment of scalds does not include bare land associated with saline groundwater.

Magnesia patches, which are bare areas caused by high near-surface concentrations of soluble salts (not linked to a watertable), are considered separately (see *Salinity – non-watertable (magnesia patches)*). Similarly, bare ground caused by near surface saline ground watertables is not considered as scalded land in this assessment.

Assessment of scalding entails an estimation of the proportion of affected land in a *Soil landscape map unit*.

Attribute Class	Presence of scalding
Z1	Not affected
Z2	Affected
ZX	Not applicable

Legend categories have been defined by calculating the proportion of land affected by scalding, as below:

Legend Category	Proportion of land affected by scalding
A	Negligible
B	Up to 5%
C	5–10%
D	10–50%
E	More than 50%
X	Not applicable

Water erosion potential

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Water erosion in this context refers to sheet or rill erosion caused by overland flow of water. *Gully erosion* and streambank erosion, *Mass movement (landslip)*, and other forms of mass erosion which are caused by water are dealt with elsewhere. This assessment does not describe existing sheet or rill erosion – by definition these forms of erosion can be obliterated by subsequent cultivation, so visible evidence of damage is transient. Nor does the assessment take any account of existing vegetative or other protective cover, which can vary significantly within and between seasons. The assumption is that any land can conceivably be at risk of erosion given a particular set of circumstances. For example, a steep hill slope with a high erosion *potential*, has a low *risk* of erosion when covered by dense native vegetation, but a high *risk* of erosion following the denuding of stabilising ground cover following a severe bushfire. Potential for erosion is therefore assessed solely on slope and soil type. If necessary, land covered by native vegetation can be excluded from the assessment by superimposing an appropriate vegetation dataset on to the *Water erosion potential* spatial data.

At the regional assessment level, slope ranges are estimated from 1:50,000 scale contour maps. *Soil landscape map units*, on which *Water erosion potential* attribute classes are based, ideally consist of only one slope range. Slope range limits are modified according to soil erodibility. Slope limits for a given *Water erosion potential* attribute class are lower for a soil which is inherently erodible, compared with those for an inherently stable soil. Soil erodibility categories, and corresponding slope range limits, are defined in the document *Assessing Agricultural Land* (Maschmedt 2002).

Soil landscape map units are categorised into legend categories according to their predominant slope range and predominant soil erodibility category. At this assessment level, slope angle is often the only component of slope that is considered. However, slope length, slope curvature, and nature of adjacent slopes are also important and can often be assessed, but subtle changes in micro-relief can make slope length difficult to assess from stereoscopic examination of aerial photographs.

As this is an assessment of *potential*, not *risk*, land is assumed to be in a bare, clean cultivated state for the purpose of making a consistent interpretation.

Legend categories are intended to have generalised management implications, but this should be viewed in a regional, sub-regional or catchment-level context. *Soil landscape map units* are categorised into legend categories according to the dominant erosion potential attribute class in the map unit. Descriptions for attribute classes and legend categories are shared, as shown below.

Attribute Class	Legend Category	Water erosion potential	Management implications
E1	A	Low	No special management needed
E2	B	Moderately low	Modified surface management needed
E3	C	Moderate	Engineered works needed (e.g. contour banks) needed if cultivated
E4	D	Moderately high	Semi arable
E5	E	High	Non arable
E6	F	Very high	Non arable, not traversable
E7	G	Extreme	Non productive
X	X	Not applicable	

Wind erosion potential

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

This assessment is intended to indicate where wind erosion could be a problem, given a particular set of conditions. The data does not depict where wind erosion has been, or is a problem. The assessment is made according to inherent landscape and soil characteristics, irrespective of vegetative or other protective cover which can vary significantly within and between seasons. Soil characteristics, mainly surface texture, and thickness of erodible soil material, together with topographic features, are used in assessing wind erosion potential. *Wind erosion potential* attribute classification criteria also take account of annual average rainfall, on the basis that the higher the rainfall, the lower the long term potential for wind erosion. Six attribute classes are defined for *Wind erosion potential*:

Attribute Class	Degree of limitation	Management implications
A1	Low	Wind erosion should not be a significant problem
A2	Moderately low	Adoption of more conservative tillage practices should minimise erosion
A3	Moderate	Reduced tillage, early sowing, modified rotations etc. needed to minimise erosion
A4	Moderately high	Specialised crops (e.g. cereal rye) and well managed pasture phases needed
A5	High	Land is non arable, careful grazing management essential
A7	Extreme	Land should not be used for cropping or grazing

A large proportion of wind erosion-prone land in South Australia occurs in complex landscapes of susceptible sandhills and more stable flats. Consequently, any regional, subregional or catchment-level assessment should incorporate both a proportionality factor to account for the varying percentages of wind erosion prone land within a *Soil landscape map unit*, and the severity of the potential problem. Legend categories are given below:

Legend Category	Wind erosion potential	
	Dominant	Subdominant
A	Low	–
B		Moderately low to moderate
C		Moderately high to extreme
D	Moderately low	Low
E		–
F		Moderate
G		Moderately high to extreme
H	Moderate	Low to moderately low
I		–
J		Moderately high to extreme
K	Moderately high	Low to moderate
L		–
M		High to extreme
N	High to extreme	Low to moderately low
O		Moderate to moderately high
P		–
X	Not applicable	

DRAINAGE AND IRRIGATION ATTRIBUTES

Deep drainage potential

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Deep drainage refers to the capacity of the deep subsoil and the material immediately below the soil profile to allow excess water to move downwards into deep sediments or fractured rock. Poorly structured or heavy clays are the most common impediment to deep drainage. The Blanchetown Clay of the Murray Basin and the equivalent Hindmarsh Clay west of the Mount Lofty Ranges are well known barriers to deep drainage.

Classes are based on an interpretation of *Soil landscape map units*. Depth classes are ascribed according to observations made during land assessment field operations.

Attribute Class	Depth to impeding layer
B1	More than 150 cm
B2	100–150 cm
B3	50–100 cm
B4	25–50 cm
B5	0–25 cm
BX	Not applicable

Assessments are based on an interpretation of *Soil landscape map units*. These may have variable deep drainage characteristics, as determined by the depth to an impeding layer. *Soil landscape map units* are categorised into legend categories according to the least well drained proportion of the landscape, provided that it accounts for at least 30% of the area of the unit. An additional legend category identifies land where limited areas have impeded deep drainage.

Legend Category	Depth to impeding layer
A	More than 150 cm
B	100–150 cm
C	10–30% of the landscape has an impeding layer within 100 cm
D	50–100 cm
E	25–50 cm
F	Less than 25 cm
X	Not applicable

Rootzone depth potential – irrigated horticultural and vegetable crops

A range of soil parameters affects the potential rootzone depth of irrigated crops. These include soil physical condition (structure), hard rock or hardpan, soluble salts, boron concentrations, alkalinity, acidity and sodicity. Furthermore, some crops are more sensitive than others to at least some of these factors. Five crop type groups are considered in these assessments. They are:

Crop type group	Indicative horticultural crop	Fact sheet	State map	Spatial data	Meta-data
CA	Sensitive perennial crops (e.g. citrus, avocado)	[Link]	[Link]	[Link]	[Link]
CB	Intermediate sensitivity perennial crops (e.g. stone fruits, almonds, pome fruits)	[Link]	[Link]	[Link]	[Link]
CC	Hardy perennial crops (e.g. grape vines, olives)	[Link]	[Link]	[Link]	[Link]
CD	Root crops (e.g. potatoes, carrots, onions)	[Link]	[Link]	[Link]	[Link]
CE	Above ground annual crops (e.g. brassicas)	[Link]	[Link]	[Link]	[Link]

Assessment of rootzone depth potential for each of these crop type groupings is as follows:

- The main *Soils (soil type)* occurring in each *Soil landscape map unit* are defined
- For each soil, criteria specified in the document *Assessing Agricultural Land* (Maschmedt 2002) are used to estimate the potential rootzone depth for each crop type group
- Average rootzone depths (based on proportions of *Soils (soil type)* within *Soil landscape map units*) are calculated for each crop type.

Soil landscape map units are categorised into legend categories according to the dominant potential rootzone depth class in the map unit. Note that variations from the mean can be significant, so legend categories should only be considered as indicative. Descriptions for attribute classes and legend categories are shared, as shown below.

Attribute Class*	Legend Category	Average potential rootzone depth
DCA1	A	More than 100 cm
DCA2	B	80–100 cm
DCA3	C	60–80 cm
DCA4	D	50–60 cm
DCA5	E	40–50 cm
DCA6	F	30–40 cm
DCA7	G	20–30 cm
DCA8	H	Less than 20 cm
DCAX	X	Not applicable

* D**CA** represents potential rootzone depth for Crop Type **CA**, but alternatively these could be substituted for D**CB**, D**CC**, D**CD**, or D**CE** to represent the other crop types listed above.

LAND SURFACE ATTRIBUTES

Exposure

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Exposure of land to wind, and to some extent to the sun, on west facing slopes can significantly reduce productivity. Assessment of exposure is highly subjective, and is designed to do no more than signal that it is a factor to consider in certain situations.

Exposure is simply assessed for the purposes of this classification by judging whether or not the land is unprotected by nearby high ground. Three *Exposure* attribute classes are considered:

Attribute Class	Degree of limitation	Relevant situations
Y1	Low	Land other than above.
Y2	Moderate	Plateaux or summit surfaces of higher elevation than the surrounding terrain.
		Hillslopes adjacent to extensive lower lying land (e.g. escarpments bordering plains).
		Upper slopes projecting above neighbouring hills.
		Moderate to high sandhills.
Y3	High	Land within five km of the coast and with direct line of sight to the sea.

Assessments are based on an interpretation of *Soil landscape map units* which are categorised into legend categories according to the proportion of the landscape with the highest degree of exposure, provided that it accounts for at least 30% of the area of the map unit.

Legend Category	Degree of exposure
A	Low
B	Moderate (plateaux, escarpments, upper slopes, moderate to high sandhills)
C	High (coastal)
X	Not applicable

Surface rockiness

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Surface rockiness refers to loose surface rocks and stones, and rocky outcrops. No attempt is made to distinguish between different types or sizes of rocks. The aim of the assessment is to describe rockiness in terms of management implication, as indicated in the descriptions of the legend categories below.

Although there are relationships between soils and surface rocks, landscapes are assessed only by visual estimates of the land surface. Where rockiness in not uniformly distributed across the map unit (e.g. a complex of sandhills and stony flats), an estimate based on proportions is made.

Soil landscape map units are categorised into seven legend categories according to the dominant *Surface rockiness* attribute class. Descriptions for attribute classes and legend categories are shared, as shown below.

Attribute Class	Legend Category	Degree of rockiness or stoniness
R1	A	No outcrop. Nil to minor surface stone
R2	B	Sufficient stones or rocks to interfere with tillage, but picking or rolling is not necessary for most uses
R3	C	Sufficient stones to necessitate picking or rolling for cultivation; or less than 10% rock outcrop, concentrated in reefs
R4	D	10–50% rock outcrop concentrated in reefs, allowing cultivation in between
R5	E	Too stony or rocky for cropping, but some pasture improvement possible, using standard equipment
R6	F	Too rocky for machinery access
R8	G	Rock pavements and rock faces
RX	X	Not applicable

Flooding susceptibility

Susceptibility to flooding imposes a serious limitation on land where structures are required. However, for some uses, floods can be beneficial, provided that energy and duration are low. Assessment of susceptibility to flooding is subjective in that generally flooding will not be observed during routine field investigations. A positive rating for *Flooding susceptibility* simply signals that there is a potential risk.

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Land is assessed for susceptibility to flooding through observation and inference. Land is simply assessed as to whether flooding is likely or unlikely. Assessments of potential frequency, severity and duration are beyond the scope of this mapping. Even the simplistic approach used in this assessment is highly subjective, and conclusions drawn should only be used to indicate flooding susceptibility in general terms. Decisions involving some specific action on the ground should under no circumstances be based on data collected in this way.

Attribute Class	Susceptibility to flooding
F1	Not susceptible
F2	Susceptible
FX	Not applicable

Assessments are based on an interpretation of *Soil landscape map units* which are categorised into five legend categories according to the proportion of area deemed susceptible to flooding.

Legend Category	Proportion of land susceptible to flooding
A	Negligible
B	1–10%
C	10–30%
D	30–60%
E	More than 60%
X	Not applicable

SOIL SALINITY ATTRIBUTES

Salinity – non-watertable

Non-watertable salinity (also known as dry saline land) is land where soils contain elevated levels of soluble salts which are not associated with a watertable. The salts have presumably accumulated in the soil either through aeolian accessions and subsequent leaching, or via saline groundwater which is no longer influencing the soil. The salts generally occur as subsoil bulges within the soil profile, which possibly reflect either the extent of leaching (i.e. salt cannot be leached any further than the depth of the seasonal wetting front), or an impermeable deep subsoil layer which prevents flushing of the salts into substrate materials.

Land where high salt concentrations extend to the soil surface and visibly affect plant growth is commonly called magnesia ground.

Soil landscapes map units are assessed for dry saline land on the basis of soil test results and extrapolation to similar soils and subsoil materials. Soil salinity concentrations are highly variable across the landscape.

Soil salinity concentrations are highly variable across the landscape – the data are therefore indicative only. Land which is affected by saline watertables is rated as either Class 1, or as for the estimated level of salinity prior to the watertable rise.

Attribute Class #	Indicative ECe (dS/m) *	
	Surface	Subsoil
V1	Less than 2	Less than 4
V2	2–4	4–8
V3	4–8	8–16
V4	8–16	More than 16
V7	Any (>50% bare ground). This class is equivalent to magnesia ground	
VX	Not applicable	

Dry saline land classes are based on the most saline part of the soil (usually the lower subsoil).

* ECe is electrical conductivity of a saturation paste of water and soil. Values are mostly based on estimates from EC (1:5) measurements.

Salinity – non-watertable

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Soil landscape map units are categorised into four legend categories according to the most severely affected proportion provided it occupies at least 30% of the area of the map unit. Land which is affected by saline watertables is rated as either low, or as for the estimated level of salinity prior to the watertable rise. Note that the map delineates areas where salinity is likely to occur.

Legend Category	Salinity #	Indicative ECe (dS/m) *	
		Surface	Subsoil
A	Low	<2	<4
B	Moderately low	2–4	4–8
C	Moderate	4–8	8–16
D	Moderately high to high	>8	>16
X	Not applicable		

Dry saline land classes are based on the most saline part of the soil (usually the lower subsoil).

* ECe is electrical conductivity of a saturation paste of water and soil. Values are based on estimates from EC (1:5) measurements.

Salinity – non-watertable (magnesia patches)

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Land where high salt concentrations extend to the soil surface and visibly affect plant growth is commonly called magnesia ground.

Attribute Class	Land affected by magnesia patches
V1,2,3,4	Land not affected by magnesia patches
V7	Land affected by magnesia patches
VX	Not applicable

Salinity – non-watertable (magnesia patches) is categorised into five legend categories according to the proportion of the *Soil landscape map unit* affected.

Legend Category	Proportion of land affected by magnesia patches
A	Negligible
B	Up to 2%
C	2–10%
D	10–50%
E	More than 50%
X	Not applicable

Salinity – watertable induced

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Soluble salts in soils affect plant growth by restricting water uptake. Plants suffer moisture stress and may eventually die. Also, some plants are affected by the direct toxic effects of soluble salts. This assessment refers to salinity which is or could conceivably be linked to watertables. Soil salinity that is a naturally occurring feature not associated with watertables is considered under the heading *Salinity – non-watertable*. Salinity has varying degrees of severity and distribution. In some districts, salinity occurs as isolated patches (saline seeps) in a landscape which is otherwise unaffected. In other districts, the effects of salinity are more uniform across the landscape.

Assessments are based on a combination of soil test results and observations of vegetation type. In general, vegetation can be used where salinity levels are moderately high or higher. For lower levels where effects are commonly sub-clinical, soil test results are used (i.e. electrical conductivity measurements) in combination with knowledge of local stratigraphy, landscapes and groundwater. The salinity attribute classes used for site assessments are:

Attribute Class	Degree of limitation	Vegetative indicators	Indicative ECe (dS/m)	
S1	Low	No evidence of salt effects	<2	Surface
			<4	Subsoil
S2	Moderately low	Subsoil salinity – deep rooted horticultural species and pasture legumes affected	<4	Surface
			4–8	Subsoil
S3	Moderate	Many field crops and lucerne affected. Halophytic species such as sea barley grass are usually evident	4–8	Surface
			8–16	Subsoil
S4	Moderately high	Too salty for most field crops and lucerne. Halophytes are common (as above plus curly rye grass and salt water couch). Strawberry clover productivity is diminished	8–16	Surface
			16–32	Subsoil
S5	High	Land dominated by halophytes with bare areas. Samphire and ice plant evident. This land will support productive species such as Puccinellia, tall wheat grass etc.	16–32	Surface
			>32	Subsoil
S7	Very high	Land is too salty for any productive plants and supports only hardy halophytes, e.g. Samphire, Swamp Tea-tree or similar	>32	Surface
S8	Extreme	Bare surface, may be salt encrusted	>32	Surface

Soil landscape map units are ranked according to the severity of salinity and proportion of land affected. The latter criterion is important, as in many landscapes, the distribution of salt affected land is highly erratic. Categories to accommodate all possible combinations of salinity level and proportion of land affected would be impractical, so seven legend categories are defined. Legend categories account for the degree of salinity of the landscape as a whole, and for the proportion of land affected by discrete highly saline seepages.

Legend Category	Watertable induced salinity
A	Negligible
B	Moderately low salinity, or less than 2% of land affected by highly saline seepage
C	Moderate salinity, or 2–10% of land affected by highly saline seepage
D	Moderately high salinity, or 10–30% of land affected by highly saline seepage
E	Moderately high to high salinity, or 30–50% of land affected by highly saline seepage
F	High salinity (mainly secondary) affects more than 50% of the land
G	Very high to extreme salinity (mainly primary)
X	Not applicable

SOIL TYPE ATTRIBUTES

Soils groups and soils

Eighteen broad *Soil groups* are identified. These are broken down into 64 *Soils (soil type).* Each *Soil landscape map unit* includes at least one soil, and there is provision for identifying up to five *Soils (soil type)* for each map unit component.

Soil groups

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Soil landscape map units are categorised into legend categories which are defined by the most commonly occurring *Soil group*. It should be noted that the most common *Soil group* frequently accounts for less than 50% of the area of the *Soil landscape map unit*. A range of unspecified *Soil groups* accounts for the balance. Attribute class and legend category descriptions are shared as shown below.

Attribute Class	Legend Category	Soil group
A	A	Calcareous soils
B	B	Shallow soils on calcrete or limestone
C	C	Gradational soils with highly calcareous lower subsoil
D	D	Hard red-brown texture contrast soils with neutral to alkaline subsoil
E	E	Cracking clay soils
F	F	Deep loamy texture contrast soils with brown or dark subsoil
G	G	Sand over clay soils
H	H	Deep sands
I	I	Highly leached sands
J	J	Ironstone soils
K	K	Shallow to moderately deep acidic soils on rock
L	L	Shallow soils on rock
M	M	Deep uniform to gradational soils
N	N	Wet soils
O	O	Volcanic ash soils
R	R	Rocks
W	W	Water
X	X	Not applicable

Soils (soil type)

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Sixty four *Soils (soil type)* are defined. Each of these soils has a two character symbol. The first character (alpha) represents the relevant *Soil group* (refer preceding table); the second character (numeric) represents the particular soil within the *Soil group*. In addition, there are three miscellaneous categories.

Soil landscape map units are categorised into legend categories according to the dominant *Soil (soil type)* in the map unit. A range of unspecified soils accounts for the balance. It should be noted that the most common soil often accounts for less than 50% of a map unit.

These *Soil (soil type)* classes are also termed 'subgroup soils' in the reference text *The Soils of Southern South Australia* (Hall et al. 2009) where they are described in detail.

Soil groups, *Soils (soil type)* Attribute Class and Legend Categories:

A Calcareous soils

A1 Highly calcareous sandy loam
A2 Calcareous loam on rock
A3 Moderately calcareous loam
A4 Calcareous loam
A5 Calcareous loam on clay
A6 Calcareous gradational clay loam
A7 Calcareous clay loam on marl
A8 Gypseous calcareous loam

B Shallow soils on calcrete or limestone

B1 Shallow highly calcareous sandy loam on calcrete
B2 Shallow calcareous loam on calcrete
B3 Shallow sandy loam on calcrete
B4 Shallow red loam on limestone
B5 Shallow dark clay loam on limestone
B6 Shallow loam over red clay on calcrete
B7 Shallow sand over clay on calcrete
B8 Shallow sand on calcrete
B9 Shallow clay loam over brown or dark clay on calcrete

C Gradational soils with highly calcareous lower subsoil

C1 Gradational sandy loam
C2 Gradational loam on rock
C3 Friable gradational clay loam
C4 Hard gradational clay loam
C5 Dark gradational clay loam

D Hard red-brown texture contrast soils with neutral to alkaline subsoil

D1 Loam over clay on rock
D2 Loam over red clay
D3 Loam over poorly structured red clay
D4 Loam over pedaric red clay
D5 Hard loamy sand over red clay
D6 Ironstone gravelly sandy loam over red clay
D7 Loam over poorly structured clay on rock

E Cracking clay soils

E1 Black cracking clay
E2 Red cracking clay
E3 Brown or grey cracking clay

F Deep loamy texture contrast soils with brown or dark subsoil

F1 Loam over brown or dark clay
F2 Sandy loam over poorly structured brown or dark clay

G Sand over clay soils

G1 Sand over sandy clay loam
G2 Bleached sand over sandy clay loam
G3 Thick sand over clay
G4 Sand over poorly structured clay
G5 Sand over acidic clay

H Deep sands

H1 Carbonate sand
H2 Siliceous sand
H3 Bleached siliceous sand

I Highly leached sands

I1 Highly leached sand
I2 Wet highly leached sand

J Ironstone soils

J1 Ironstone soil with alkaline lower subsoil
J2 Ironstone soil
J3 Shallow soil on ferricrete

K Shallow to moderately deep acidic soils on rock

K1 Acidic gradational loam on rock
K2 Acidic loam over clay on rock
K3 Acidic sandy loam over red clay on rock
K4 Acidic sandy loam over brown or grey clay on rock
K5 Acidic gradational sandy loam on rock

L Shallow soils on rock

L1 Shallow soil on rock

M Deep uniform to gradational soils

M1 Deep sandy loam
M2 Deep friable gradational clay loam
M3 Deep gravelly soil
M4 Deep hard gradational sandy loam

N Wet soils

N1 Peat
N2 Saline soil
N3 Wet soil (low to moderately saline)

O Volcanic ash soils

O1 Volcanic ash soil

Miscellaneous

RR Rock
WW Water
XX Not applicable

Surface soil texture

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Surface texture refers to the approximate clay content of the surface soil. Texture is determined in the field by manipulating a moistened soil sample between the fingers and assessing its sandiness and strength. Texture influences many soil qualities including waterholding capacity, nutrient retention capacity, erodibility, permeability, workability and seedling emergence. Some of these are assessed as soil or land attributes in their own right.

For some purposes, an estimate of the most commonly occurring surface texture in a *Soil landscape map unit* provides the best information for a user. There are 15 *Surface soil texture* classes, with a range of qualifiers. These are aggregated into eight classes in the attribute mapping system. These attribute classes are used as generalised legend categories, and are listed with approximate clay contents below:

Attribute Class	Surface texture	Approximate clay content
S	Sand	Less than 5%
LS	Loamy sand, clayey sand	5–10%
SL	Sandy loam, fine sandy loam	10–20%
L	Loam, silty loam, light sandy clay loam	About 25%
SCL	Sandy clay loam	20–30%
CL	Clay loam, silty clay loam, fine sandy clay loam	30–35%
CN	Non cracking clay	More than 35%
CC	Cracking clay	More than 35%
X	Not applicable	

Soil landscape map units often have a range of surface textures. Therefore, *Soil landscape map units* are categorised into legend categories according to their most common surface texture where this accounts for less than 60% of the map unit, and a qualifier is in other cases to indicate whether the majority of other soils have coarser (more sandy) or finer (more clayey) textured surfaces.

Legend Category	Dominant surface texture	Subdominant surface texture (mainly coarser or mainly finer)
A	More than 60% sand	–
AF	More than 30% sand	Finer
B	More than 60% loamy sand	–
BC	More than 30% loamy sand	Coarser
BF	More than 30% loamy sand	Finer
C	More than 60% sandy loam	–
CC	More than 30% sandy loam	Coarser
CF	More than 30% sandy loam	Finer
D	More than 60% loam	–
DC	More than 30% loam	Coarser
DF	More than 30% loam	Finer
E	More than 60% sandy clay loam	–
EC	More than 30% sandy clay loam	Coarser
EF	More than 30% sandy clay loam	Finer
F	More than 60% clay loam	–
FC	More than 30% clay loam	Coarser
FF	More than 30% clay loam	Finer
G	More than 60% clay	–
GC	More than 30% clay	Coarser
X	Not applicable	

SOIL MOISTURE ATTRIBUTES

Available waterholding capacity

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

The effective depth of a soil, as determined by physical and chemical barriers, together with the clay content of the soil within that depth, determine the waterholding capacity of the profile, and how much of the water is available to plants. Effective soil depth varies between plant species. Wheat is used as the benchmark plant in this assessment. *Available waterholding capacity* attribute classes are estimated from soil texture, structure and stone content within the potential rootzone of a wheat plant.

The features affecting waterholding capacity vary substantially across the landscape and within *Soil landscape map units*. Waterholding capacities for the characteristic soils of each *Soil landscape map unit* are estimated (from morphological properties, not laboratory analyses). Each *Soil landscape map unit* is categorised into legend categories according to the estimated average available waterholding capacity of its soils, on a proportional basis. Five legend categories are used. It should be borne in mind that each legend category is an average, and variation can be significant. Descriptions for attribute classes and legend categories are shared, as shown below.

Attribute Class	Legend Category	Average available waterholding capacity	
M1	A	High	More than 100 mm
M2	B	Moderate	70–100 mm
M3	C	Moderately low	40–70 mm
M4	D	Low	20–40 mm
M5	E	Very low	Less than 20 mm
MX	X	Not applicable	

Depth to watertable

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

This assessment is intended to provide a general indication of the occurrence of landscapes where watertables are sufficiently shallow to affect plant growth. As the information is derived from soil landscape mapping and not a specific watertable survey, there is a significant amount of estimation based on the local knowledge of land resource assessment specialists. For example, often field work is done during the drier months when watertable levels are typically lower than late winter/early spring maximum heights.

In this assessment, watertable depth is assessed on the maximum level maintained for at least two weeks per year. This definition is based on the concept that most plants will be affected by watertable induced waterlogging which persists for more than two weeks.

Assessments are based on an interpretation of *Soil landscape map units*. These may have variable depths to watertable. *Soil landscape map units* are categorised into legend categories according to the part of the landscape with the shallowest depth to watertable, provided that it accounts for at least 30% of the area of the unit. Additional legend categories identify land where limited areas have watertables shallower than 100 cm and 200 cm. No distinction is made between saline and non-saline watertables (the *Salinity - watertable induced* attribute can be used to determine the spatial extent of shallow saline watertables).

Attribute Class	Legend Category	Depth to watertable
O1	A	More than 200 cm
	B	More than 200 cm over at least 70% of the landscape, but shallower in places
O2	C	100–200 cm
	D	Shallower than 100 cm over 10–30% of the landscape
O3	E	50–100 cm
O4	F	0–50 cm
O5	G	Above surface for up to 3 months
O7	H	Above surface for 3–10 months
O8	I	Above surface for more than 10 months
OX	X	Not applicable

Recharge potential

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

The purpose of this assessment is to delineate those areas where there is potential for un-used water to enter the groundwater system via the soil profile. The assessment is based on the assumption that recharge is a function of soil profile waterholding capacity, substrate porosity and rainfall. (Position in the landscape, depth to watertable, and the presence of soil layers restrictive to drainage are also considered.) Because the soil landscape mapping program concentrated on soils and the materials immediately beneath them, the nature of substrates is commonly estimated from local knowledge and/or an understanding of regional stratigraphy. In fractured rock environments such as the Mount Lofty–Flinders Ranges system, steeply dipping rock strata and consequent spatial variability across the landscape complicate these estimates. *Recharge potential* is rated using three attribute classes (Q1=Low, Q2=Moderate, Q3=High), and is estimated according to the following guidelines:

Soil waterholding capacity	Substrate porosity	Degree of limitation		Attribute Class	
		Mod-low rainfall *	High rainfall *	Mod-low rainfall *	High rainfall *
>100 mm	Low	Low	Low	Q1	Q1
	Mod	Low	Low	Q1	Q1
	High	Low	Low	Q1	Q1
40–100 mm	Low	Low	Low	Q1	Q1
	Mod	Low	Mod	Q1	Q2
	High	Mod	High	Q2	Q3
<40 mm	Low	Low	Mod	Q1	Q2
	Mod	Mod	High	Q2	Q3
	High	High	High	Q3	Q3

* High rainfall is defined as more than 800 mm annual average in hilly districts (where a significant proportion of rainfall is lost to runoff), and more than 650 mm in non-hilly districts such as the lower South East.

Assessments are based on an interpretation of *Soil landscape map units*. Recharge potential can vary significantly between the components of a *Soil landscape map unit*. Each map unit is categorised into *Recharge potential* legend categories according to the proportions of high and moderate recharge potential.

Legend Category	Proportion of land with high or moderate recharge potential	
	High recharge	Moderate recharge
A	Negligible	Negligible (i.e. low recharge potential)
B	Negligible	Up to 30%
C	Negligible	More than 30%
D	Up to 30%	Up to 30%
E	Up to 30%	More than 30%
F	30–60%	Up to 30%
G	30–60%	More than 30%
H	More than 60%	Any
X	Not applicable	

Waterlogging susceptibility

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Waterlogging occurs when all or part of the soil profile is saturated with water. Some soils are effectively never waterlogged, while others are saturated all of the time. The degree to which a soil becomes waterlogged depends on how much water enters the soil and how quickly it leaves it, either by deep percolation, lateral seepage or evapo-transpiration. Clearly, low lying ground is more prone to waterlogging than higher ground, and, just as clearly, areas which get little rain or have excessive runoff are unlikely to be significantly affected. The permeability of the soil, depth to watertable, and position in the landscape all affect susceptibility to waterlogging.

Soil landscape map units are assessed according to the period of time that all or part of the soil profile is waterlogged. This is invariably an estimate based on observable soil and landscape features, and on opportunistic recordings of soil wetness under different weather conditions. The level of waterlogging is rarely consistent within a landscape. *Soil landscape map units* are categorised into legend categories according to their most waterlogged areas, provided that those areas account for at least 30% of the total. It is possible therefore, that up to 70% of a particular *Soil landscape map unit* is less severely affected by waterlogging than the map suggests. It is not the purpose of the assessment to identify specific parts of the landscape which are susceptible to waterlogging. Rather, the intent is to define those *Soil landscape map units* within which waterlogging is a potential problem, and to provide an indication of the severity of the problem.

Note, that in the attribute class criteria, *Waterlogging susceptibility* is indicated by drainage condition (i.e. the better the drainage, the lower is the susceptibility to waterlogging).

Legend categories for *Soil landscape map units* are based on the most susceptible part of the landscape, using the 30% minimum occurrence concept as outlined above. Legend category C has been included to enable identification of land where limited areas (i.e. less than 30%) are subject to moderate to severe waterlogging. Descriptions for *Waterlogging susceptibility* attribute classes and legend categories are shared, as shown below.

As a general rule, legend categories E through to H are non arable.

Attribute Class	Legend Category	Waterlogging susceptibility / degree of wetness	
W1	A	Rapidly to well drained	Soil is rarely wet for more than several days
W2	B	Moderately well drained	Soil is wet for up to one week
	C	10–30% of the landscape is imperfectly to very poorly drained	
W3	D	Imperfectly drained	Soil is wet for several weeks
W4	E	Imperfectly drained	Soil is wet for several weeks early in growing season.
W5	F	Poorly drained	Soil is wet for several months
W7	G	Very poorly drained	Soil is wet for most of the year
W8	H	Inundated	Land is permanently under water
WX	X	Not applicable	

SOIL PHYSICAL CONDITION ATTRIBUTES

Depth to hard rock or hardpan

Hard rock or hardpan at shallow depth influence not only the effective rootzone of plants, but also impact on engineering uses of land. Hard rock or hardpan is defined as material which is too hard to dig with hand tools. Hard rock is basement or country rock, many millions of years old, which generally occurs at or near the surface in the hilly country of the Mount Lofty Ranges, Northern Agricultural Districts, Eastern and Lower Eyre Peninsula, Central Yorke Peninsula and Kangaroo Island. Hardpan on the other hand is cemented or indurated material, in or below the soil, developed as part of soil forming processes. Hardpans are generally (relatively) young materials. Hardpans in southern South Australia include calcrete, ferricrete and silcrete. Calcrete is by far the most common, being widespread on Eyre and Yorke Peninsulas, Murraylands, the South East and Gulf Plains. Hard rock is distinguished from hardpan because the former tends to become harder with depth, in contrast to hardpans which are generally hardest at the top, and become softer with depth. This clearly has major implications for dealing with hard material.

Depth to hard material is routinely measured during field survey where it occurs within a metre or so of the surface. Typical depths are defined for the range of soils occurring within a *Soil landscape map unit*, which is categorised into legend categories according to the estimated average depth to hardpan, on a proportional basis. Six depth legend categories are defined. There is often significant variation from the assigned category within a *Soil landscape map unit*. The legend category represents an average depth value only. Descriptions for attribute classes and legend categories are shared, as shown below.

Depth to hard rock

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Attribute Class	Legend Category	Average depth to hard rock
XR1	A	More than 150 cm
XR2	B	100–150 cm
XR3	C	50–100 cm
XR4	D	25–50 cm
XR5	E	10–25 cm
XR6	F	Less than 10 cm
XRX	X	Not applicable

Depth to hardpan

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Attribute Class	Legend Category	Average depth to hardpan
XP1	A	More than 150 cm
XP2	B	100–150 cm
XP3	C	50–100 cm
XP4	D	25–50 cm
XP5	E	10–25 cm
XP6	F	Less than 10 cm
XPX	X	Not applicable

Soil structure and physical condition

Soil structure is a much used and generally poorly understood term. In this context it refers to the degree of resistance offered by the soil to root penetration and seedling emergence, to the free movement of air and water, and to the ease of cultivation and other surface management operations. It is therefore an integration of assessments of strength, aggregation and porosity.

Three datasets can be used to produce maps of soil structure. One deals with surface soil, one with subsoil, and the third deals with arable land only and combines surface and subsoil. Assessments are based on an interpretation of *Soil landscape map units*. Surface soil condition in particular varies significantly across the landscape and is affected by management practice as well as by inherent properties of the soil. The assessments only indicate where soil structural problems could potentially be significant, and do not define specific occurrences of particular conditions.

Physical condition of surface soil

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The most significant surface soil physical limitation in South Australia is the condition known as hard setting. Hard setting soils and the surface seals which develop on them have low infiltration rates (leading to surface ponding of water, or excessive runoff/erosion), have a narrow moisture range for effective working, which can result in patchy emergence. Hard setting soils generally have high proportions of fine sand and silt, and insufficient swelling clay content to allow for internal volume changes. The clay particles may be dispersive, and organic matter levels may be low, but these latter are not prerequisite for hard setting.

Soil landscape map units are consequently categorised into legend categories according to the proportion of their area susceptible to hard setting and/or sealing surfaces.

Legend Category	Proportion of land with surface soils susceptible to hard setting or sealing
A	Negligible
B	Less than 10%
C	10–30%
D	30–60%
E	More than 60%
X	Not applicable

Structure of subsoil (degree of limitation)

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Poor subsoil structure is commonly attributable to sodic or dispersive clay, although in soils where there is an abrupt break between the topsoil and subsoil, non dispersive materials can impede water and air movement and root growth. Poorly structured subsoils at shallow depth present a greater limitation than those which are deeper in the profile, so the assessment of subsoil structure is an integration of structure type and depth, as follows:

Attribute Class	Degree of limitation	Typical depth to:	
		Dispersive clay	Poorly structured non dispersive clay *
P1	Low	More than 60 cm	More than 30 cm
P2	Moderately low	30–60 cm	20–30 cm
P3	Moderate	20–30 cm	10–20 cm
P4	High	10–20 cm	Less than 10 cm
P5	Very high	Less than 10 cm	–

* Poorly structured but non dispersive subsoils have coarse blocky or prismatic aggregates, or are massive and hard.

Each soil occurring within a *Soil landscape map unit* is assigned a rating (low to very high limitation). Map units are categorised into legend categories according to the most limiting subsoil structure condition, provided that it accounts for more than 30% of the area. Two additional legend categories identify land where there are limited occurrences (i.e.10–30%) of soil structure limitation.

Legend Category	Degree of limitation due to subsoil structure
A	Low
B	Low with 10–30% moderately low to moderate
C	Moderately low
D	Low to moderately low with 10–30% moderate to very high
E	Moderate
F	High
G	Very high
X	Not applicable

Physical condition of soil (surface and subsoil combined)

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

The purpose of this assessment is to identify potential soil structure limitations on arable land, by using four simplified categories:

- no significant problems
- surface soil only
- subsoil only
- surface and subsoil

Each *Soil landscape map unit* is categorised into legend categories according to its most limiting soil physical condition, provided that it occupies 30% or more of the area. Subsoil structure limitations of moderate, high and very high define ‘poor subsoil structure’ in this assessment. Land which is non arable due to one or more of waterlogging, salinity, rockiness or steepness is also considered.

Legend Category	Physical condition of soil
A	No significant structure problems
B	Mixture of Categories D and E (10–30% of map unit)
C	Sandy / friable surface, with poorly structured subsoil
D	Hard setting / sealing surface, but subsoil structure is not a significant limitation
E	Hard setting / sealing surface, and poor subsoil structure
W	Too wet and / or saline for cropping
N	Too rocky or steep for farm equipment
X	Not applicable

Water repellence

LINKS TO:
[Fact sheet]
[State map]
[Spatial data]
[Metadata]

Water repellence is caused by hydrophobic organic materials, mainly waxes, contained in plant remains in the soil. The waxes coat the soil particles causing water to bead on the surface. This causes uneven wetting of the upper part of the profile with large masses of soil remaining dry. Patchy plant establishment, uneven and poor growth usually result. Water repellence increases susceptibility to both water erosion, wind erosion and sand blasting of newly emerged plants, and contributes to increased recharge.

Water repellence is most common on acid to neutral sands, but calcareous and more loamy soils can also be affected, although not as severely.

Water repellence is assessed into three attribute classes by observing the absorption into a soil sample of either water or 2 M ethanol, e.g.:

Attribute Class	Degree of limitation	Brief description
U1	Non repellent	Water is absorbed in less than 10 seconds
U2	Repellent	Water takes longer than 10 seconds to be absorbed; ethanol is absorbed in less than 10 seconds
U3	Strongly repellent	Ethanol takes longer than 10 seconds to be absorbed

In practice, water repellence is highly variable both spatially and temporally. Estimates for *Soil landscape map units* are made according to tests on soil samples, and on extrapolation between similar soils in similar environments. Experience over a wide range of situations across southern South Australia has shown that certain soils commonly exhibit strong water repellence, and others are susceptible but the condition is less strongly developed. Regional, subregional and catchment assessments are not intended to show where water repellence is a problem, but where conditions are such that it could be a problem.

Water repellence is extensive in dune–swale landscapes, where spatial distribution is very uneven (i.e. high likelihood on dunes and sand spreads, lower likelihood in swales). Consequently it is useful to map susceptibility to water repellence as a proportion of the landscape. Legend categories therefore indicate both the severity of potential repellence and the approximate percentage of the *Soil landscape map unit* which is susceptible.

Assessments are based on an interpretation of *Soil landscape map units*. Each map unit is categorised into legend categories according to the proportion of its area at risk of water repellence, based on the extent of susceptible soils. Where more than 10% of land is susceptible, there is a further subdivision according to the degree of repellence.

Legend Category	Proportion of land affected and degree of water repellence
A	Negligible to minor
B	10–30% moderately repellent and / or 1–10% strongly repellent
C	30–60% moderately repellent
D	More than 60% moderately repellent
E	10–30% strongly repellent
F	10–30% strongly repellent and more than 60% moderately repellent
G	30–60% strongly repellent
H	60–90% strongly repellent
I	More than 90% strongly repellent
X	Not applicable

FURTHER INFORMATION

Soil and Land Attribute Data spatial downloads, available from Data.SA

DEWNR Soil and Land Information:
http://www.environment.sa.gov.au/Science/Information_data/soil-and-land

NatureMaps is an interactive online mapping site supporting South Australia's natural resource management, which displays soil and land information across southern South Australia. Spatial data can be downloaded from this site. See http://www.naturemaps.sa.gov.au/ (>Soils).

AgInsight South Australia is an interactive website that gives users comprehensive agricultural and economic data. AgInsight displays various Land Use Potential for Agricultural Land datasets.

References

Hall, J.A.S., Maschmedt, D.J. and Billing N.B. (2009). *The Soils of Southern South Australia*. The South Australian Land and Soil and Book Series, Volume 1; Geological Survey of South Australia, Bulletin 56, Volume 1. Department of Water, Land and Biodiversity Conservation, Government of South Australia. (Download from Enviro Data SA: Part 1 and Part 2)

Maschmedt, D.J. (2002). *Assessing Agricultural Land.* Soil and Land Program, Department of Water, Land and Biodiversity Conservation, South Australia.