Land resources of the Bencubbin area

Gerard J. Grealish

John Wagnon

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Land resources of the Bencubbin Area

Gerard Grealish and John Wagnon
Cover:
Karomin Hill, north of Nungarin is a granite rock exposed in an upper landscape position on a long gentle slope that extends to the floor of a broad very flat valley. This is typical of the Bencubbin area landscape.
Land resources of the

BENCUBBIN AREA

By Gerard Grealish and John Wagnon

Editor: Georgina Wilson

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Summary

This survey of the Bencubbin area is part of the Agriculture Western Australia's regional land resource mapping program, and covers approximately 1.5 million hectares in the Merredin, Trayning, Koorda, Mount Marshall, Mukinbudin, Westonia and Nungarin Shires of Western Australia. The climate is Mediterranean, with hot dry summers and cool winters. Land is used for winter cereal production and grazing, and about 60% is cropped each year. Wheat is the main crop and is grown in rotation with lupins, field peas, barley and medic pasture.

This report provides primary and interpreted information on the character and capability of the land, for use at regional, catchment and farm levels. The five major outputs or datasets are:

- a site database of soil and landforms
- description of map units
- description of soil series
- a soil landscape map at a scale of 1:250,000
- interpretation of the data.

The 1:250,000 scale map and 14 soil landscape map units at subsystem level indicate the landform pattern and enable prediction of soil property variation at a regional level. Land capability interpretations can be made for broad regional planning. For farm scale use, the survey identifies and describes 18 soil series. This provides a basis for more detailed mapping and land use interpretation. Soils are identified within a common framework throughout the region and this grouping will aid the extension of local experience and experimental research results.
Contents

Introduction 5
How to use this report 7
History of land use 8
Climate 9
Geology and physiography 12
Native vegetation 14
Previous soil surveys 15
Survey methods 17
Map units 19
Soil series 40
Landscape processes 82
Soil assessment 83
Glossary 90
Acknowledgments 92
References 93
Appendix (soil series headings and laboratory analysis) 96
Other Land Resources Series Reports 98

List of figures
1. Bencubbin survey area in relation to Perth and the rest of Western Australia 5
2. Average annual rainfall received in the survey area 9
3. An idealised laterite profile 13
4. Cross-section diagram showing modification of the laterised Tertiary landscape 13
5. Location of previous surveys and relation to present survey area 16
6. Distribution of described soil sites 18
7. Hierarchy of map units used in this report 20
8. Guide to identifying soils in the field 42

List of tables
1. Summary of monthly rainfall patterns 10
2. Average daily minimum, maximum and mean monthly temperatures for Bencubbin and Merredin towns 11
3. Correlation between the Bencubbin survey map units and those of adjacent surveys 23
4. Map units of the Bencubbin area ordered from highest to lowest landscape position and related to soil series 24
5. Distribution of soils series in each system map unit 45
6. Soil properties important to land use, often required to make management decisions 86
7. Susceptibility of soil series to various forms of degradation 89
Introduction

This report provides information on the soils and landforms of the Bencubbin area. This information is required by farmers, land managers and planners to assist in making decisions on how best to manage the land resources. At regional level the information can be used for land use planning and conservation policy; at farm level it is a tool for planning rational and sustainable land use. Land resource information also facilitates the extension of experimental results and knowledge of how the soil and land perform under different management.

Before this survey, soil information was provided for the area by the *Atlas of Australian Soils* [Northcote 1967] at a map scale of 1:2,000,000 using soil map units with brief descriptions. This provided a framework for further soil mapping but had insufficient detail for farm planning and land management purposes. This new report provides improved soil and land resource information where only limited data was previously available.

This survey was instigated by the Department of Agriculture (now Agriculture Western Australia) because of the demand for primary soil and land resource information from the farming community. The demand was stimulated by an increased focus on sustainable land use by the Decade of Landcare program, which has led to greater awareness of degradation problems (salinity, surface structure decline, acidification, wind and water erosion), the need to produce farm plans to improve management, and to target suitable areas for pasture, crops and trees.

*Figure 1. Bencubbin survey area in relation to Perth and the rest of Western Australia.*
This survey is part of a program to map the soil landscape resources of the agricultural areas of Western Australia. It was funded by the National Landcare Program and is part of the Merredin Regional Soil Survey. The survey was carried out between August 1990 and October 1991.

This report provides soil and landform information for the Bencubbin area (see Figure 1). The accompanying 1:250,000 scale soil landscape map shows the land system and subsystem map units used. Soils are identified within the map units and soil series descriptions provide detailed information about these soils.

The Bencubbin area is on the eastern margin of the Western Australian wheatbelt, and experiences hot dry summers and cool winters. The survey covers about 1.5 million hectares including part of Merredin, Trayning, Koorda, Mount Marshall, Mukinbudin, Westonia and Nungarin Shires.

*Cereal cropping is the major industry of the Bencubbin area and railway sidings and grain receival bins such as Nembudding are common.*
How to use this report

The report and accompanying map have three main functions:
• to identify the soil or a soil property at a point or area of interest
• to show the distribution of soils or soil properties
• to aid in the production of suitability or risk maps.

To identify the soil or a soil property at a point or area of interest:
1. Locate the point or area of interest on the map.
2. From the map identify the map unit and symbol for the point of interest, e.g. Tr for Trayning Subsystem.
3. Go to the map legend and locate the map symbol (the map unit colour will also assist).
4. The map legend will show for the map unit
   i) full map unit name, ii) brief landscape description, iii) the soil series and their approximate percentages within the map unit.
5. Within the map unit a number of soil series will be identified, therefore it will be difficult to determine exactly which one is at your point of interest. In the report the section on map units contains detailed information about each unit and may help to determine the likely soils. If not, it should be assumed that any of the soils for that unit could occur.
6. The report section on soil series provides detailed information about the soils. These are arranged alphabetically and contain data about the soil properties under headings including classification, land management, representative profile description, physical and chemical laboratory analysis, and references to other analysed soils.

To show the distribution of soils or soil properties:
1. In the section on soil series, identify from the descriptions the series which contain the information of interest. It may be that the soil series or a soil property is of interest.
2. Identify the soil series in the map legend. It is possible that a series may occur in more than one map unit.
3. Each map unit has a symbol and associated colour. This aids in locating it on the map, and therefore the location of the soil or soil property of interest across the survey area.
4. The map unit section provides description of the likely locations for soil series within the map unit. This could be used to better locate a soil in the field, e.g. it may identify that the soil occurs on a footslope within the map unit.

To aid in the production of suitability or risk maps:
(This first requires an interpretation to be made of the soil property information found in the soil series descriptions.)
1. Allocate each of the soil series to a suitability or risk class according to the interpretation.
2. Identify the relevant map units in the map legend, and allocate a class to each map unit.
3. Redraw the map as a class map showing suitability or risk for a particular land use.


History of land use

The survey area covers part of a region known as the Western Australian wheatbelt which stretches eastward to the limit of the agricultural areas. The Bencubbin area was first explored in 1836 by J.S. Roe who was followed by sandalwood cutters. The first European settlers were pastoralists who herded sheep along the salt lake chains, broad valley floors and around rock outcrops. These areas were accessible and had feed and water.

In 1887 the pastoralist landholders were encouraged to practise agriculture. The heavier country in the valleys was cleared first for cropping and grazing because the upland sandplains were deficient in some essential nutrients. Completion of railway lines to Southern Cross in 1894, Koorda in 1917 and Bonnie Rock in 1931, provided links with the main centres of York, Northam and Perth. Mechanisation took over from horses in the 1920s and land was cleared more easily.

Since that time, farms have spread east and northwards from the railway lines and main tracks. The spread of agriculture continued until areas of less reliable rainfall were reached - in some years inadequate to sustain crop growth. This marginal country is adjacent to uncleared Crown Land and pastoral leases.

Farms are now highly mechanised using large machinery and run by family units with hired help. Farm size ranges from 1,000 to 10,000 ha averaging about 2,500 ha. Farming is predominantly winter grain cropping (mainly wheat in rotation with lupins and field peas) and sheep on improved (legume) pasture. About 50 to 60% of the land is cropped each year, rotations varying with soil type.

No mining occurs in the area except for a small amount of gypsum harvesting near salt lakes, and pure quartz quarrying and crushing west of Mukinbudin.

Hay cut from crop edges before harvesting serves a double purpose for local farmers ensuring a firebreak around paddocks and a fodder reserve for late summer and autumn.
Climate

The area has a Mediterranean climate with hot dry summers and cool winters. A summary of climatic data for shires is presented in the *Land management manual – Merredin advisory district* [Frost and Howell 1990]. Average annual rainfall is between 275 and 300 mm, 70% received between May and October. Rainfall is the most important climatic variable as it has a major effect in determining both productivity and land degradation. The 300 mm rainfall isohyet dissects the survey area as shown in Figure 2. Areas to the east can expect average annual rainfall to be less than 300 mm. A summary of monthly rainfall patterns is provided in Table 1.

Temperatures for Bencubbin and Merredin towns are summarised in Table 2. Average daily temperatures recorded at Bencubbin for January range from a minimum of 18°C to a maximum of 34°C with a mean of 26°C. In July they range from 6 to 16°C, with a mean of 11°C. Total evaporation in the Bencubbin area for Class A pans ranges from 2,600 to 2,950 mm a year [Frost and Howell 1990].

*Figure 2. Average annual rainfall received in the survey area.*
Table 1. Summary of monthly rainfall patterns [from Frost and Howell 1990].

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Table 2. Average daily minimum, maximum and mean monthly temperatures for Bencubbin town averaged over 33 years, and for Merredin town averaged over 66 years [from Frost and Howell 1990].

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Geology and physiography

The area lies within the Yilgarn Craton, a stable area of Archaean (4,600 to 3,000 million years old) gneiss and granite. The youngest Archaean intrusions of granite and adamellite (quartz monzonite) outcrop as irregular circular shapes. After regional metamorphism and deformation had ceased, numerous Proterozoic (3,000 to 600 million years ago) dolerite, diorite and quartz-feldspar dykes were intruded. These occur in parallel swarms (similar composition and age) and with trends controlled by the regional tectonic pattern often in an easterly or north-easterly direction.

These basement rocks are overlain by Cainozoic (<60 million years ago) superficial deposits. Two groups are recognised, but have evolved from a continuous erosion process. The Tertiary (60 to 1.8 million years) group comprises sediments eroded from an older land surface, and the Quaternary (<1.8 million years) group comprises deposits that still are being formed from the breakdown of both the Tertiary deposits and Archaean bedrock. The parent material of the soils is mainly these Tertiary and Quaternary sediments.

Geology is described by the 1:250,000 scale geology maps and explanatory notes for Kellerberrin, Bencubbin and Jackson sheets [Blight 1984, Chin 1983, 1986].

The present topography developed during the Cainozoic era (last 60 million years). Geological and climatological events leading to the present day are described in detail by McArthur [1993] and Bowler [1976, 1982].

The Yilgarn Craton has been stable since the Palaeozoic era (600 million years ago), and during this time was subject to sub-aerial weathering and erosion. Moist temperate to tropical climate led to high rates of rock weathering during the Late Tertiary period (20 million years ago). This resulted in a landscape of very low relief with a mantle of strongly weathered material up to 50 metres thick. The weathering pattern was commonly in the form of a laterite profile (Figure 3), consisting of a sandy or gravelly (ironstone) surface, underlain by mottled and pallid horizons of weathered material, sitting on weathered rock (saprolite) and bedrock.

The main drainage system probably developed during the Late Cretaceous period (135 to 65 million years ago) and regular river flow in inland areas ceased by the mid-Miocene (10 million years ago) [van de Graff et al. 1977]. Chains of playa lakes (seasonal salt lakes) have developed along these palaeodrainage lines and flow between them occurs rarely.

The full laterite profile is still preserved along drainage divides [Bettenay 1962] but elsewhere it is extensively eroded. The product of the erosion has filled the palaeodrainage valleys. McArthur [1993] provides a detailed review of this erosion process in relation to the current land surfaces recognised by Bettenay and Hingston [1964] (see Figure 4) and aeolian accumulations around salt lakes [Bettenay 1962].

This generally accepted landscape model of an old lateritic plateau being eroded and replaced by a younger one is based on a model of Jutson [1934]. However, Ollier et al. [1988] theorise that this is too simple and propose a new geomorphic chronology with many episodes of erosion and deposition, and formation of lateritic soils.
Figure 3. An idealised laterite profile [from Lantzke and Fulton 1993].

Gravely sand or rock
Ironstone caprock (duricrust)
Mottled zone (sandy clay rich in iron and aluminium oxides)
Pallid zone (white to pink sandy clay of kaolinite mineralogy)
Weathered rock (saprolite)
Bedrock

Figure 4. Cross-section diagram showing modification of the laterised Tertiary landscape [from Bettenay and Hingston 1964].

The result of these geomorphological processes is the present day gently undulating landscape with low relief at an elevation between 250 and 500 m. The drainage divides are wide and convex, slopes are long and gentle (about 2 to 8%), the main valleys are very wide (2 to 6 km) with a very low gradient (about 1 in 1500) and contain salt lakes. Joining these are tributary valleys which are wide (about 2 km) with a low gradient (about 1 in 500). The area lies east of the Meckering Line and has been called the Zone of Salt Lakes and Sandplains [Mulcahy 1967] and the Zone of Ancient Drainage [Lantzke and Fulton 1993].
Native vegetation

Before European settlement and clearing for agriculture, the natural vegetation consisted of salmon gum (*Eucalyptus salmonophloia*), gimlet (*E. salubris*) and wandoo (*E. wandoo*) woodlands, *Acacia* and *Melaleuca* shrubland, *Eucalyptus* mallees and heath.

This has now been cleared extensively, except for small remnant strips along roadsides and a few nature reserves. Beard produced 1:250,000 scale maps and explanatory notes for the area [1980a,b]. They describe the expected variation in natural vegetation communities based on field observation and prediction using aerial photo interpretation.

In the past, broad generalisations have been used to associate soil with vegetation, e.g. thicket on sandplain on the higher ground; woodland on red loam on lower ground; mallee (*Eucalyptus* spp.) on duplex soils; gimlet on heavy clay subsoils; salmon gum and gimlet on shallow sandy loam over an alkaline clay; York gum (*E. loxophleba*) and jam (*A. acuminata*) on granitic sandy soils; wodjil (*Acacia* spp.) on yellow acidic sands; and tamma (*Allocasuarina corniculata*) on yellow sands.

Although vegetation can be a useful soil indicator, there is not a one-to-one relationship, therefore these broad generalisations cannot be used for soil landscape mapping. In addition, the native vegetation that might give clues to soils has been cleared from most agricultural land.

The largest patches of remnant vegetation are often associated with rock outcrops. This one near Lake Brown consists of York gum, mallee and jam.
Previous soil surveys

Teakle [1938] first described the broad soil patterns in the south-west of Western Australia based on the work of Prescott [1931, 1933]. This survey area was separated into two subregions:

- undulating hills with woodland soils and valleys with light sandy and gravelly soils;
- broad flat woodland valleys with sandy and gravelly rises.

Two unpublished soil surveys covering about 150,000 ha at a scale of 1:15,846 (4 inches to a mile), the Soil surveys at Lake Brown [Teakle 1931] and Cleary soil survey [Teakle 1936], classified and mapped seven main soil types. These surveys were confined mainly to woodland areas in valleys surrounding salt lakes. Their purpose was to describe and map the soil types, and identify alkali problems associated with unsatisfactory crop returns. No conclusions were reported.

The soils and land use of the Merredin area, Western Australia [Bettenay and Hingston 1961], a survey covering 2000 square kilometres around the Merredin township, has provided the basis for describing the soils and their distribution for a major part of this eastern wheatbelt region. The 1:126,720 (1 inch to 2 miles) scale map uses soil associations as the mapping units. Analytical data for the soil types is provided in a separate report [Hingston and Bettenay 1961]. A detailed survey of the Merredin Agricultural Research Station [Bettenay 1960], using soil types as the mapping units, provides detailed description of how individual soils are related in part of this landscape.

Bettenay and Hingston [1964] related the soil pattern to recognisable landscape features. Five surfaces were described and are shown in a cross-section of the modified laterised Tertiary landscape (Figure 4). This is commonly recognised as the descriptive landscape pattern for much of this region. The surfaces have not been mapped, but erosional and depositional phases had been recognised within them and they have been used for detailed mapping using soil associations [Bettenay and Hingston 1961]. There is much confusion between the use of the same names for the land surface e.g. Ulva land surface [Bettenay and Hingston 1964], the soil mapping unit e.g. Ulva soil association [Bettenay and Hingston 1961], and the soil series e.g. Ulva Soil Series [Bettenay and Hingston 1961].

The entire region has been mapped at 1:2,000,000 scale as Sheet 5 of the Atlas of Australian Soils [Northcote et al. 1967]. The mapping units are soil associations generally delineated by landscape. This map has been the main source of information on regional soil distribution.

Recent surveys in the region at a 1:100,000 scale have been undertaken at the southern boundary (Figure 5). They are Land resources of the Kellerberrin region [McArthur 1992] and Land resources of the Northam region [Lantzke and Fulton 1993]. These surveys were at similar scale to the Merredin survey [Bettenay and Hingston 1961] but use subsystem soil-landscape mapping units. They identify, describe and interpret the soil series that occur within the subsystems.
Further detailed soil profile and chemical data are published in *A handbook of Australian soils* [Stace et al. 1968], and *Reference soils of south-western Australia* [McArthur 1991]. Two recent publications provide descriptions of the common soils in the Merredin Advisory District, with a qualitative interpretation of the soil capability based on advisory and research staff experience. They are *Land management manual, Merredin advisory district* [Frost and Howell 1990] and *An introduction to the soils of the Merredin advisory district* [Stoneman 1992].
Survey methods

The procedures used for the present survey were:

- Review of previous work in the area.
- Field reconnaissance to identify soils already described.
- Identification of preliminary map unit boundaries by stereo air photo interpretation (1:50,000, black and white photos WA2029, WA2030 January 1982, WA2191 January 1984).
- Use of 1:100,000 rectified Landsat TM images on bands 3, 5 and 7 (112-81F, 111-81C, 111-82C December 1988) to assist in delineating boundaries.
- Choice of sites using the free survey technique [Gunn et al. 1988] to describe soil profiles and identify their relationship to the landscape. They were also used to test and improve the conceptual models for mapping.
- Description of soil profiles and their environment according to the *Australian soil and land survey field handbook* [McDonald et al. 1984] and coding to Agriculture Western Australia standards. Data were recorded manually on site cards and later recorded digitally onto the WARIS database [Purdie 1993a]. Soil profiles were described from pits and/or hand auger borings to a depth of 1 m, where possible.
- Development of conceptual models relating the various sources of evidence (field data, previous resource data, photo interpretation, published soil process and development models) to soil variation. A synthesis of this material was used to draw map boundaries and identify the soils that are predicted to occur within them.
- Adjustment of map unit boundaries to fit the conceptual subsystem models. Rectified 1:100,000 scale Landsat TM images were used as the mapping base.
- Sampling of soil pits at reference sites for chemical and physical analysis.
- Identification and description of soil series [Purdie 1993], incorporating the Australian Soil Classification [Isbell 1989, 1995].
- Assessment of land qualities which affect the capability of the land to sustain a specific use without undesirable on-site or off-site effects. This qualitative assessment was based on surveyor, Agriculture Western Australia advisory and research staff, and farmer experience.
- Downloading of soil profile and site data to Agriculture Western Australia soil profile database [Peluso 1993]. Map line work was stored in a Geographical Information System (Microstation MGE/MGA); map units and soil series descriptions as individual word processor files according to Purdie’s format [1993b]. All data is held by the Natural Resources Assessment Group.

Field work was undertaken between May and November 1991 over about 1.5 million ha. Winter rainfall was very low and drought conditions existed throughout most of the area. The low rainfall meant that heavier textured subsoils were often dry making it difficult to recover good soil samples for description.

About 700 soil profiles were described (1 per 2000 ha) and their distribution is shown in Figure 6. Their detail ranges from comprehensive descriptions from soil pits (data point) to abbreviated description from auger borings (observation point). Soil class was determined for another 350 sites and recorded on aerial photographs. Laboratory analysis was carried out on samples from selected sites.
Figure 6. Distribution of described soil sites.

The bobtail (*Tiliqua rugosa*) is a common sight in warmer months throughout the survey area.
**Map units**

Map units partition the landscape so that a more precise prediction about a soil’s occurrence and distribution can be made than for the whole survey area. They identify areas that have similar soil and landforms which can be interpreted more easily in terms of land management.

Two kinds of mapping units are used for soil and land resource inventory:

- Soil-landscape units (e.g. land systems) are delineated with the aid of remote sensing techniques such as aerial photographs. They are defined on landform and the pattern of geology, soil and vegetation within the landform.

- Soil units (e.g. soils, soil associations and soil complexes) are delineated by changes in soil properties. Map boundaries are determined by field work; landscape features are generally not used.

Soil-landscape map units are used in this survey because large areas can be covered rapidly. The broad mapping scale and low intensity of sampling do not allow soils to be mapped.

Agriculture Western Australia has established a hierarchy of soil-landscape map units in order to maintain a consistent approach with different mapping scales and varying levels of complexity in both landscape and soil patterns [Purdie 1993b]. Moving down the hierarchy the map units cover increasingly smaller areas and the internal complexity decreases (Figure 7). Each map unit in Western Australia has a unique symbol indicating how it fits into the mapping unit hierarchy, e.g. 258Tr indicates the map unit is in Western Region 2, Avon Province 25, Zone of Ancient Drainage 258, Trayning System 258Tr.

Systems of the hierarchy are identified in this survey. These could be further subdivided into subsystems and land facet or land management units.

Sheep for wool are an important source of income for farmers in the survey area.
Figure 7. Hierarchy of soil-landscape map units used in this report.

1. **Regions**
   Broad subdivisions of the Australian continent
   e.g. The Western Region (2)

2. **Provinces**
   Suitable for maps at scales of about 1:5,000,000
   providing a broad overview of the whole State
   e.g. The Avon Province (25)

3. **Zones**
   Areas defined on geomorphological or geological
   criteria, suitable for regional perspectives
   e.g. Zone of Ancient Drainage (258)

   Bencubbin survey area
   (Survey areas usually occur within zones or may
   cover parts of several zones)

4. **Systems**
   Areas with recurring patterns of landforms, soils and
   vegetation suitable for regional mapping
   e.g. Trayning System (258Tr)
Accompanying map

The Bencubbin area was mapped at a scale of 1:250,000. The map legend describes the landscape and identifies the soil series for each system map unit. Statements about mapping units apply to the whole survey area; individual delineations may differ considerably from this ‘norm’ in terms of the proportion of different soils and landforms that occur within them. Thus the map provides a guide to what may occur at a particular point or selected area, not a definitive statement.

The full survey area map is a representation of the land reality. Soils form a continuum in the landscape, therefore unit boundaries are placed by surveyor judgement on evidence available at the scale of mapping. They do not indicate sharp changes, but a zone where the rate of soil and landscape variation is greatest.

Land systems

Fourteen land systems have been identified. They are defined on physiographic criteria and consider climate, geology, landform, soil and native vegetation patterns.

The land system summaries provide a broad description of landform and soil variation for the area. To the south, the landscape is dissected and undulating, with many exposed rock outcrops. Upland areas are small, slopes are short, and valleys are broad and flat. To the north the landscape is dominated by undulating upland and large broad valleys with salt lakes. Tributary valleys are short, slopes are gently inclined and short. The survey area is dominated by broad flat valleys and very long gentle slopes rising to granite rock outcrops or an undulating upland sandplain. To the east the landscape is dissected, containing isolated sandplain areas and rock outcrops.

Salt encroachment is a serious threat in many low lying areas such as the Wallambin System.
Two systems may have the same landform but are named as different because the grouping of soils within them is different (e.g. Trayning and Cleary Systems).

The map unit boundaries were based on broad landform features which could be determined by aerial photo interpretation. Field investigation identified the soil pattern within the unit thus allowing the type of system to be identified.

The system description includes the type of landform, native vegetation likely to occur and the soils that are found in the unit. If possible the distribution of the soil within the unit and its abundance are described. It should be noted that these were assessed using surveyor judgement. Statistical analysis of the site data cannot be used as sites were selected using a free survey method and therefore biased. The percentages should be used as a guide only to indicate major and minor soils within each map unit.

A correlation of the Bencubbin survey map units and those of adjacent previous surveys is shown in Table 3. This should only be used as an approximate guide as the map units in this survey are different from the adjacent surveys which were undertaken in greater detail.

Positions in the landscape for the system units and their constituent soil series are shown in Table 4.

*Knungajain Hill, north-east of Nungarin, is a large steep-sided granite rock. Such outcrops are typical in the Kwelkan System.*
## Table 3. Correlation between the Bencubbin survey map units and those of adjacent surveys.

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<th>Soil-landscape systems</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Booraan, Ulva, Collgar</td>
</tr>
<tr>
<td>Wallambin</td>
<td></td>
<td></td>
<td></td>
<td>Booraan, Ulva, Collgar</td>
</tr>
<tr>
<td>Wialki</td>
<td></td>
<td></td>
<td></td>
<td>Booraan, Ulva, Collgar</td>
</tr>
<tr>
<td>Yelbeni</td>
<td></td>
<td></td>
<td></td>
<td>Booraan, Ulva, Collgar</td>
</tr>
<tr>
<td>Yetelling</td>
<td></td>
<td></td>
<td></td>
<td>Booraan, Ulva, Collgar</td>
</tr>
<tr>
<td></td>
<td>Nangeenan, Merredin</td>
<td>Merredin, Collgar</td>
<td>Merredin, Collgar</td>
<td>Merredin, Collgar</td>
</tr>
<tr>
<td></td>
<td>Booraan, Ulva, Collgar</td>
<td>Merredin, Collgar</td>
<td>Merredin, Collgar</td>
<td>Merredin, Collgar</td>
</tr>
<tr>
<td></td>
<td>Merredin, Collgar</td>
<td>Baandee</td>
<td>Baandee</td>
<td>Baandee, Stirling</td>
</tr>
<tr>
<td></td>
<td>Ulva, Booraan</td>
<td>Ulva, Booraan</td>
<td>Ulva, Booraan</td>
<td>Ulva, Booraan</td>
</tr>
</tbody>
</table>

Note: This table is to be used as a guide only for comparison between maps. There are no direct relationships.

*Small breakaways are common on the higher slopes, particularly on the eastern margin of the survey area in the Nembudding System.*
Table 4. Map units of the Bencubbin area ordered from highest to lowest landscape position and related to soil series.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>System Name</th>
<th>Landscape (based on relief and modal slope class, McDonald et al. 1990)</th>
<th>Soil series (Series name and estimated % in the map unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UPLANDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ko</td>
<td>Koorda</td>
<td>Gently undulating rises, may contain small valleys and minor channels</td>
<td>Norpa 35%  Holleton 25%  Cunderdin 15%  Ulva 15%  Beacon 2%  Northam-1 2%  Elabbin 2%  Jura 2%  Rock outcrops 2%</td>
</tr>
<tr>
<td>Ye</td>
<td>Yelbeni</td>
<td>Gently undulating plains and rises</td>
<td>Ulva 40%  Norpa 20%  Cunderdin 10%  Holleton 10%  Booraan 6%  Elabbin 4%  Jura 4%  Rock outcrops 4%  Northam-1 2%</td>
</tr>
<tr>
<td><strong>INTERMEDIATE AREAS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wi</td>
<td>Wialki</td>
<td>Undulating rises</td>
<td>Mollerin 40%  Booraan 30%  Korbel 13%  Jura 5%  Beacon 4%  Rock outcrops 4%  Elabbin 2%  Northam-1 2%</td>
</tr>
<tr>
<td>Ne</td>
<td>Nembudding</td>
<td>Undulating rises to low hills, with occasional abrupt erosional scarps (breakaways)</td>
<td>Booraan 60%  Ulva 15%  Jura 8%  Rock outcrops 8%  Collgar 5%  Elabbin 2%  Northam-1 2%</td>
</tr>
<tr>
<td>Kw</td>
<td>Kwelkan</td>
<td>Undulating to rolling low hills, with granite rock outcrops</td>
<td>Rock outcrops 35%  Jura 30%  Booraan 10%  Ulva 5%  Cunderdin 5%  Norpa 5%  Elabbin 3%  Northam-1 2%</td>
</tr>
</tbody>
</table>
### INTERMEDIATE AREAS

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yt</td>
<td>Yetelling Undulating low hills, with greenstone rock outcrops</td>
<td>Unnamed 80%, Ulva 10%, Northam-1 10%</td>
</tr>
<tr>
<td>Nu</td>
<td>Nungarin Gently undulating plains, in the lower slope and upper valley floor position</td>
<td>Collgar Collgar-1 Booraan 40%, Korbel 15%, Merredin-1 10%, Booraan 5%</td>
</tr>
</tbody>
</table>

### VALLEYS

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>Cleary Gently undulating plains, that are tributary to the main valleys</td>
<td>Beacon 50%, Mollerin 30%, Korbel 10%, Merredin 5%, Nangeenan 5%</td>
</tr>
<tr>
<td>Tr</td>
<td>Trayning Level to gently undulating plains, that are tributary to the main valleys</td>
<td>Merredin 35%, Merredin-1 30%, Neening 17%, Collgar 5%, Collgar-1 5%, Nangeenan 5%, Korbel 3%</td>
</tr>
<tr>
<td>Ga</td>
<td>Gabbabin Gently undulating plains, below a greenstone unit and tributary to Lake Wallambin</td>
<td>Unnamed 70%, Beacon 10%, Merredin 10%, Merredin-1 5%, Korbel 5%</td>
</tr>
<tr>
<td>Ba</td>
<td>Baladjie Gently undulating plains, that are tributary to and part of the Lake Baladjie salt lake valley</td>
<td>Merredin 25%, Beacon 25%, Merredin-1 15%, Nangeenan 15%, Collgar 10%, Hines Hill 10%</td>
</tr>
<tr>
<td>Mu</td>
<td>Mukanbuddin Level plains, that are very broad and form part of the main valleys</td>
<td>Beacon 40%, Nangeenan 20%, Merredin 15%, Merredin-1 10%, Neening 8%, Korbel 5%, Salt lakes 2%</td>
</tr>
<tr>
<td>Ku</td>
<td>Kununoppin Level to gently undulating plains, that form part of the main valleys and fringe salt lakes</td>
<td>Nangeenan 50%, Hines Hill 25%, Merredin 10%, Merredin-1 5%, Beacon 5%, Neening 5%</td>
</tr>
<tr>
<td>Wa</td>
<td>Wallambin Level plains, that are part of the main valleys containing salt lakes</td>
<td>Salt lakes and channels 60%, Hines Hill 20%, Unnamed 20%</td>
</tr>
</tbody>
</table>
Baladjie System

20,100 ha 1% of the survey area

The Baladjie System occurs on gently undulating plains which form the floor and lower slopes of valleys that are tributary to, or part of the major salt lake drainage systems. The valleys are broad (2 to 3 km wide), with extremely low relief (<9 m in 300 m radius) and have very gently inclined slopes (<2%). Native vegetation is a woodland with a shrub understorey. Soils are alkaline, red gradational loam to clay (Beacon, Nangeenan, Merredin Series), and texture contrast sandy loam over clay (Merredin-1, Collgar Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>25</td>
<td>Valley floor, lower slope</td>
</tr>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>25</td>
<td>Valley floor, lower slope</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>15</td>
<td>Valley floor, lower slope</td>
</tr>
<tr>
<td>Nangeenan</td>
<td>Calcic Calcarosol</td>
<td>15</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Hines Hill</td>
<td>Calcic Calcarosol</td>
<td>10</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Collgar</td>
<td>Grey Kandosol</td>
<td>10</td>
<td>Valley floor</td>
</tr>
</tbody>
</table>

Soil 23

Salt lake

Systems

Wallambin

Baladjie

Wallambin or Nembudding

slopes <2 %
2 to 3 km

slope <2 %

2 to 3 km
**Cleary System**

60,700 ha 4% of the survey area

The Cleary System occurs on gently undulating plains that form broad (>2 km wide) valley floors with extremely low relief (<9 m in 300 m radius) and very gently inclined slopes (<2%). Typically, the valleys have one main stream channel, and are tributary to the main salt lake drainage system. Native vegetation is a salmon gum and gimlet woodland with shrub understorey. Soils include a sandy loam topsoil grading to a red clay alkaline subsoil (Beacon Soil Series), and a red sandy topsoil grading to an alkaline red sandy clay loam overlying a hardpan (Mollerin Soil Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>50</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Mollerin</td>
<td>Red Kandosol</td>
<td>30</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>10</td>
<td>Footslope</td>
</tr>
<tr>
<td>Nangeenan</td>
<td>Calcic Calcarosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
</tbody>
</table>

Systems

Koorda, Cleary, Wialki
**Gabbabin System**

8,700 ha  
<1% of the survey area

The Gabbabin System occurs on gently undulating plains that form on valley floors (<2 km wide), with extremely low relief (<9 m in 300 m radius) and very gently inclined slopes (<2%). The parent material is colluvium and alluvium sourced from greenstone containing metamorphic rock. Soils are sandy loam grading to alkaline red clay loam (Beacon, Merredin Series) and texture contrast sandy loam overlying a red clay loam (Merredin-1, Korbel Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unnamed*</td>
<td></td>
<td>70</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>10</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>10</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>5</td>
<td>Valley floor and lower slopes</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>5</td>
<td>Valley floor and lower slopes</td>
</tr>
</tbody>
</table>

* Unnamed soil is a loam over a red clay.
Koorda System

285,600 ha  19% of the survey area

The Koorda System occurs on gently undulating rises in upland areas. The unit is extensive, covering large areas which may include small valleys with minor channels. Relief is very low to extremely low (<30 m and commonly <15 m in 300 m radius), with long (200 to 500 m) very gently inclined slopes (1 to 3%). Heath and shrubland native vegetation occurs throughout the unit with minor areas of salmon gum on the crests. The soils are predominantly deep, yellow sands (Norpa, Cunderdin Series), gravel loams (Ulva Series) and acidic sands (Holleton Series). Minor soils are calcareous, red clay loams (Beacon Series) occurring on crests, a shallow, coarse sandy loam on kaolinised rock (Elabbin Series) associated with breakaways, and a well structured, alkaline, red clay soil associated with dolerite dykes (Northam-1 Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norpa</td>
<td>Orthic Tenosol</td>
<td>35</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Holleton</td>
<td>Orthic Tenosol</td>
<td>25</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>Orthic Tenosol</td>
<td>15</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Ulva</td>
<td>Orthic Tenosol</td>
<td>15</td>
<td>Mid-slope</td>
</tr>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>2</td>
<td>Crest</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Red Vertosol</td>
<td>2</td>
<td>With dolerite dykes</td>
</tr>
<tr>
<td>Elabbin</td>
<td>Brown Kurosol</td>
<td>2</td>
<td>Breakaways</td>
</tr>
<tr>
<td>Jura</td>
<td>Red Kandosol</td>
<td>2</td>
<td>Associated with rock outcrops</td>
</tr>
<tr>
<td>Rock outcrops</td>
<td></td>
<td>2</td>
<td>All slope positions</td>
</tr>
</tbody>
</table>

Soil series

Cunderdin
Holleton
Norpa
Beacon
Northam-1
Elabbin
Ulva

 Systems

slope 1 to 3 %
5 to 10 km

Kwelkan Koorda Nembudding
**Kununoppin System**

107,100 ha  7% of the survey area

The Kununoppin System occurs on level to gently undulating plains that form valley floors and lower slopes. The unit fringes salt lakes and occurs predominantly on their southern and eastern margins. Relief is extremely low (<9 m in 300 m radius), with level to very gently inclined slopes (<3%). Native vegetation is morrel and salmon gum woodland with a shrub understorey. Soils are formed in parna derived from salt lakes. They are calcareous, red loams grading to clay, often with a fluffy surface (Nangeenan, Hines Hill, Beacon, Merredin Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nangeenan</td>
<td>Calcic Calcarosol</td>
<td>50</td>
<td>Valley floor and lower slopes</td>
</tr>
<tr>
<td>Hines Hill</td>
<td>Calcic Calcarosol</td>
<td>25</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>10</td>
<td>Valley floor and lower slopes</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>5</td>
<td>Valley floor and lower slopes</td>
</tr>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Neening</td>
<td>Calcic Calcarosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Salt lakes</td>
<td></td>
<td>&lt;1</td>
<td>Valley floor</td>
</tr>
</tbody>
</table>

Salt lakes <1 Valley floor

Soil 2 c a) c .c a) .c O o -o .c -o series ca a) o) O a cc E ER C cu cD ir) a) ± z co M z m

Salt lake slope <3%
2 to 3 km wide

Systems Wallambil Kununoppin Trayning
**Kwelkan System**

190,100 ha  13% of the survey area

The Kwelkan System occurs on undulating to rolling low hills, with granite rock outcrops. The unit occurs in all landscape positions, and has low relief (9 to 90 m in 300 m radius), gently to moderately inclined slopes (3 to 20%). Stream channels are common. Native vegetation is York gum and jam bushland. Soils are dominated by gritty quartz sand to sandy loam, formed in weathered granite and granite colluvium (Jura Series). They vary greatly in depth. Other soils reflect transitions to adjacent map units.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite outcrops</td>
<td></td>
<td>35</td>
<td>Crests to mid-slope</td>
</tr>
<tr>
<td>Jura</td>
<td>Red Kandosol</td>
<td>30</td>
<td>Fringing rock outcrops</td>
</tr>
<tr>
<td>Booraan</td>
<td>Brown Sodosol</td>
<td>10</td>
<td>Mid to lower slope</td>
</tr>
<tr>
<td>Ulva</td>
<td>Orthic Tenosol</td>
<td>10</td>
<td>Shoulder to lower slope</td>
</tr>
<tr>
<td>Norpa</td>
<td>Orthic Tenosol</td>
<td>5</td>
<td>Crest to lower slope</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>Orthic Tenosol</td>
<td>5</td>
<td>Crest to lower slope</td>
</tr>
<tr>
<td>Elabbin</td>
<td>Brown Kurosol</td>
<td>3</td>
<td>Breakaway</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Red Vertosol</td>
<td>2</td>
<td>With dolerite dykes</td>
</tr>
</tbody>
</table>

- **Soil series**
  - **Cunderdin**
  - **Norpa**
  - **Jura**
  - **Rock outcrop**
  - **Ulva**
  - **Elabbin**
  - **Booraan**

- **Systems**
  - Yelben
  - Kwelkan
  - Nembudding

- **Slope**
  - 3 to 20%
  - 1 to 5 km
Mukinbudin System

72,700 ha  5% of the survey area

The Mukinbudin System occurs on level plains, which are very broad (3 to 6 km) and flat (<1%), with extremely low relief (<9 m in 300 m radius), and form part of the main drainage lines. Although this unit is almost the lowest in the landscape there are only a few salt lakes. Native vegetation is woodland with a shrub understorey. Soils are commonly gradational, alkaline, red loam to red clay loam, with soft carbonates in the profile (Beacon, Nangeenan Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>40</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Nangeenan</td>
<td>Calcic Calcarosol</td>
<td>20</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>15</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>10</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Neening</td>
<td>Calcic Calcarosol</td>
<td>8</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Salt lakes</td>
<td></td>
<td>2</td>
<td>Valley floor</td>
</tr>
</tbody>
</table>

Soil systems

- **Mukinbudin**
- **Nembuddin**
- **Trayning**
- **Merredin**
- **Nangeenan**
- **Beacon**
- **Korbel**
- **Drainage channel**

*slope <1 %
3 to 6 km wide*
**Nembudding System**

241,300 ha  16% of the survey area

The Nembudding System occurs on undulating rises to low hills, between the upland areas and the valleys. Relief is low (9 to 60 m in 300 m radius) with gently inclined slopes (3 to 8%). Breakaways may be present and are more common in the east. Native vegetation is largely cleared and includes mallee bush and woodland. A variety of soils occurs in this unit, along with some rock outcrops. The dominant soil has a texture contrast with a hardsetting sandy loam surface over a calcareous, reddish clay subsoil (Booraan Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booraan</td>
<td>Brown Sodosol</td>
<td>60</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Ulva</td>
<td>Orthic Tenosol</td>
<td>15</td>
<td>Upper slope</td>
</tr>
<tr>
<td>Jura</td>
<td>Red Kandosol</td>
<td>8</td>
<td>Fringing rock outcrops</td>
</tr>
<tr>
<td>Rock outcrops</td>
<td>Grey Kandosol</td>
<td>8</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Collgar</td>
<td>Red Vertosol</td>
<td>5</td>
<td>Lower slope</td>
</tr>
<tr>
<td>Elabbin</td>
<td>Brown Kurosol</td>
<td>2</td>
<td>Upper slope, below breakaways</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Red Vertosol</td>
<td>2</td>
<td>Associated with dolerite dykes</td>
</tr>
</tbody>
</table>

Soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Collgar</th>
<th>Booraan</th>
<th>Jura</th>
<th>Rock outcrop</th>
<th>Booraan</th>
<th>Elabbin</th>
<th>Ulva</th>
</tr>
</thead>
</table>

Systems

- Trayning
- Nembudding
- Yelbeni

slope 3 to 8 %
0.5 to 2.5 km
Nungarin System

40,300 ha  3% of the survey area

The Nungarin System occurs on gently undulating plains, which form in the lower slopes of tributary valleys. Relief is extremely low (<9 m in 300 m radius), with very gently inclined slope (1 to 3%). Native vegetation is mainly mallees. This unit is dominated by texture contrast soils of sand overlying clay, often with bleached sandy subsurface horizons and a siliceous hardpan at depth (Collgar, Collgar-1, Korbel Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collgar</td>
<td>Grey Kandosol</td>
<td>40</td>
<td>Footslope and valley floor</td>
</tr>
<tr>
<td>Collgar-1</td>
<td>Grey Sodosol</td>
<td>30</td>
<td>Footslope</td>
</tr>
<tr>
<td>Booraan</td>
<td>Brown Sodosol</td>
<td>15</td>
<td>Lower slope</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>10</td>
<td>Footslope</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
</tbody>
</table>

Soil series


e-2

Slope 1 to 3 %
0.5 to 2 km wide

34
**Trayning System**

96,200 ha  6% of the survey area

The Trayning System occurs on a level to gently undulating plain, which forms a broad (about 2 km wide) valley floor, with extremely low relief (<9 m in 300 m radius) and near level slopes (<2%), in valleys that are tributary to the main salt lake chain. Typically, the valley has one main stream channel. Native vegetation includes woodland with a shrub understorey. Soils vary from a greyish brown cracking clay (Neening Series), to a hardsetting, calcareous gradational (sandy loam grading to reddish brown clay) soil (Merredin Series), and texture contrast soils (Merredin-1, Collgar, Korbel Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merredin</td>
<td>Calcic Calcarosol</td>
<td>35</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Merredin-1</td>
<td>Red Sodosol</td>
<td>30</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Neening</td>
<td>Calcic Calcarosol</td>
<td>17</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Collgar</td>
<td>Grey Kandosol</td>
<td>5</td>
<td>Footslope and valley floor</td>
</tr>
<tr>
<td>Collgar-1</td>
<td>Grey Sodosol</td>
<td>5</td>
<td>Footslope</td>
</tr>
<tr>
<td>Nangeenan</td>
<td>Calcic Calcarosol</td>
<td>5</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>3</td>
<td>Footslope</td>
</tr>
</tbody>
</table>
Wallambin System

120,800 ha 8% of the survey area

The Wallambin System occurs on level plains. Salt lakes, interconnecting salt drainage channels and surrounding dunes are dominant features of this unit which occurs in the lowest landscape position. The valley widths vary greatly (1 to 6 km), and relief is extremely low (<9m in 300 m radius) with level slopes (<1%). Native vegetation is samphire and saltbush with scattered gums. The salt lakes have bare surfaces. In winter they contain water but dry to a surface of salt crystals in summer. Soils surrounding the salt lakes are weakly developed and alkaline, with a loamy surface that grades to clay with depth (Hines Hill Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt lakes and salt channels</td>
<td></td>
<td>60</td>
<td>Valley floor, lowest position</td>
</tr>
<tr>
<td>Hines Hill</td>
<td>Calcic Calcarosol</td>
<td>20</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Unnamed-1*</td>
<td></td>
<td>15</td>
<td>Valley floor fringing lakes</td>
</tr>
<tr>
<td>Unnamed-2*</td>
<td></td>
<td>5</td>
<td>Dunes surrounding lakes</td>
</tr>
</tbody>
</table>

* Unnamed-1 is a sand over a mottled gleyed clay.
* Unnamed-2 is a calcareous and/or gypsum sand. Pure gypsum dunes occur near Lake Campion.
**Wialki System**

92,400 ha 6% of the survey area

The Wialki System occurs on undulating rises which form intermediate slopes between the upland units and valleys. Relief is very low (9 to 30 m in 300 m radius) with gently inclined slopes (3 to 8%). Breakaways, rock outcrops, dolerite dykes and stream channels are occasionally present. Native vegetation includes salmon gum woodlands. A variety of soils can be found in this unit, the main ones being red texture contrast soils with sandy loam over sandy clay loam to medium clay subsoils (Booraan Series) and red sandy soil on hardpan (Mollerin Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mollerin</td>
<td>Red Kandosol</td>
<td>40</td>
<td>Lower slope</td>
</tr>
<tr>
<td>Booraan</td>
<td>Brown Sodosol</td>
<td>30</td>
<td>All slope positions</td>
</tr>
<tr>
<td>Korbel</td>
<td>Red Kandosol</td>
<td>13</td>
<td>Lower slope</td>
</tr>
<tr>
<td>Jura</td>
<td>Red Kandosol</td>
<td>5</td>
<td>Associated with rock outcrops</td>
</tr>
<tr>
<td>Rock outcrops</td>
<td></td>
<td>4</td>
<td>Upper to mid-slope</td>
</tr>
<tr>
<td>Beacon</td>
<td>Calcic Calcarosol</td>
<td>4</td>
<td>Mid to lower slope</td>
</tr>
<tr>
<td>Elabbin</td>
<td>Brown Kurosol</td>
<td>2</td>
<td>Below breakaways</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Red Vertosol</td>
<td>2</td>
<td>Associated with dolerite dykes</td>
</tr>
</tbody>
</table>

**Soil series**

- **Mollerin** Red Kandosol 40 Lower slope
- **Booraan** Brown Sodosol 30 All slope positions
- **Korbel** Red Kandosol 13 Lower slope
- **Jura** Red Kandosol 5 Associated with rock outcrops
- **Rock outcrops** 4 Upper to mid-slope
- **Beacon** Calcic Calcarosol 4 Mid to lower slope
- **Elabbin** Brown Kurosol 2 Below breakaways
- **Northam-1** Red Vertosol 2 Associated with dolerite dykes

**Systems**

- **Cleary**
- **Wialki**
- **Koorda**

Slope 3 to 8 %

2 to 4 km wide
**Yelbeni System**

166,800 ha 11% of the survey area

The Yelbeni System occurs on gently undulating plains and rises in upland areas. The unit typically has very low to extremely low relief (<15 m in 300 m radius) with long (100 to 300 m), very gently inclined slopes (1 to 3%). Native vegetation of heath and shrubland occurs throughout with very minor areas of mallee and woodland. The soils are predominantly deep, yellow acidic sand and sandy loam (Holleton and Norpa Series), acidic gravelly loam (Ulva Series) and deep, yellow neutral sand (Cunderdin Series). A shallow, coarse sandy soil on kaolinised rock is associated with breakaways (Elabbin Series), and a well structured, red alkaline clay is associated with dolerite dykes (Northam-1 Series).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulva</td>
<td>Orthic Tenosol</td>
<td>40</td>
<td>Crest, upper to mid-slope</td>
</tr>
<tr>
<td>Norpa</td>
<td>Orthic Tenosol</td>
<td>20</td>
<td>Upper to mid-slope</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>Orthic Tenosol</td>
<td>10</td>
<td>Upper to mid-slope</td>
</tr>
<tr>
<td>Holleton</td>
<td>Orthic Tenosol</td>
<td>10</td>
<td>Upper to mid-slope</td>
</tr>
<tr>
<td>Booraan</td>
<td>Brown Sodosol</td>
<td>6</td>
<td>Mid-slope</td>
</tr>
<tr>
<td>Rock outcrops</td>
<td>Brown Kurosol</td>
<td>4</td>
<td>Crest, upper to mid-slope</td>
</tr>
<tr>
<td>Elabbin</td>
<td>Red Kandosol</td>
<td>4</td>
<td>Associated with breakaways</td>
</tr>
<tr>
<td>Jura</td>
<td>Red Vertosol</td>
<td>2</td>
<td>Associated with rock outcrops</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Red Vertosol</td>
<td>2</td>
<td>Associated with dykes</td>
</tr>
</tbody>
</table>
**Yetelling System**

2,900 ha  
<0.5% of the survey area

The Yetelling System occurs on undulating low hills, which are associated with a belt of greenstone (mafic) rocks. The topography is angular, unlike the surrounding rolling granite landscape. Relief is low (30 to 60 m in 300 m radius) and slopes are gently inclined (3 to 10%), but with angular rock outcrops. The native vegetation is mallee bush with minor salmon gum woodlands. The soils have not been described fully.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Australian Soil Classification</th>
<th>Abundance (%)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unnamed*</td>
<td>Orthic Tenosol</td>
<td>80</td>
<td>Slopes</td>
</tr>
<tr>
<td>Ulva</td>
<td>Red Vertosol</td>
<td>10</td>
<td>Slopes</td>
</tr>
<tr>
<td>Northam-1</td>
<td>Orthic Tenosol</td>
<td>10</td>
<td>Slopes</td>
</tr>
</tbody>
</table>

* Unnamed is a sandy loam over a sandy clay loam overlying doleritic material.
Soil series

Soils were identified and described as soil series. A series defines soils with a limited range of morphological, chemical, physical and mineralogical properties that can be managed as a single unit for most present and anticipated land uses. Standardised criteria [Purdie 1993b] were used to identify the soil series. Eighteen soil series have been recognised and these span six Soil Orders of the Australian Soil Classification [Isbell 1989, 1995]:

- Vertosols (clay soils with marked shrink-swell properties): Northam-1 Soil Series
- Kurosols (strongly acid soils with a marked texture contrast): Elabbin Soil Series
- Sodosols (dispersive soils with a marked texture contrast): Booraan, Collgar-1 and Merredin-1 Series
- Kandosols (moderately developed structured B horizon lacking a marked texture contrast): Collgar, Jura, Korbel and Mollerin Soil Series
- Tenosols (weakly developed B horizons, lacking a marked texture contrast): Cunderdin, Holleton, Norpa and Ulva Soil Series
- Calcarosols (calcareous soils lacking a marked texture contrast): Beacon, Hines Hill, Merredin, Nangeenan and Neening Soil Series.

The soil series are described briefly below, followed by detailed information. A key to their field recognition is shown in Figure 8. Heading descriptions and chemical analysis used are explained in the Appendix. For each series, a representative profile is included with laboratory analysis, if available. Variants of soil series are designated by the series name and a hyphenated numerical suffix. Table 5 shows the distribution of soil series in each system, from which area has been estimated.

**Beacon Soil Series:** This is a Calcic Calcarosol. It has a red alkaline loam topsoil. At >30 cm depth it grades to a moderately structured, highly alkaline red clay subsoil with soft carbonates. Below 50 cm it is sodic.

**Booraan Soil Series:** This is a Brown Sodosol. It has a hardsetting, reddish brown, sandy loam topsoil. At <30 cm depth there is an abrupt change to a reddish brown, sodic sandy clay containing soft and nodular carbonates.

**Collgar Soil Series:** This is a Grey Kandosol. It has a hardsetting, clayey sand topsoil, overlying a massive, bleached subsurface horizon. At 30 to 80 cm depth this grades to a moderately structured, alkaline, gravelly sandy clay loam. This overlies a siliceous hardpan at >80 cm depth.

**Collgar-1 Soil Series:** This is a Grey Sodosol. It has a hardsetting, clayey sand topsoil, overlying a massive, bleached subsurface horizon. At <30 cm depth there is an abrupt change to a moderately structured, alkaline, sodic, clay subsoil. This overlies a siliceous hardpan at >80 cm depth.

**Cunderdin Soil Series:** This is an Orthic Tenosol. It has a yellowish brown sand topsoil. At >80 cm depth it grades to a deep slightly acidic, uniform, massive, porous, yellowish clayey sand.

**Elabbin Soil Series:** This is a Brown Kurosol. It has a hardsetting, acidic coarse sandy loam topsoil. At <30 cm depth it grades to an acidic clay loam. The profile is generally shallow, overlying decomposed rock or saprolite.
**Hines Hill Soil Series:** This is a Calcic Calcarosol. It has a very fluffy, greyish brown, sandy loam topsoil. At 30 to 80 cm it grades to a reddish brown sandy clay loam. The profile is alkaline with soft carbonates throughout, and sodic below 50 cm.

**Holleton Soil Series:** This is an Orthic Tenosol. It has a greyish brown, sand to clayey sand topsoil. At <30 cm depth it grades to a massive, yellowish sand to sandy clay loam. The profile is acidic throughout.

**Jura Soil Series:** This is a Red Kandosol. It has a reddish brown gritty loamy sand topsoil. At <30 cm depth it grades to a weakly structured, reddish gritty sandy loam to clay loam. This overlies weathered granite at varying depths.

**Korbel Soil Series:** This is a Red Kandosol. It has a hardsetting, reddish brown sandy loam topsoil. At 30 to 80 cm depth it grades to a mottled, reddish clay loam. This overlies a hardpan.

**Merredin Soil Series:** This is a Calcic Calcarosol. It has a hardsetting, sandy clay loam topsoil. At <30 cm depth it grades to a structured sodic alkaline reddish brown clay, containing soft and nodular carbonates.

**Merredin-1 Soil Series:** This is a Red Sodosol. Topsoil is hardsetting, reddish brown, neutral sandy loam. At <30 cm depth there is an abrupt change to a sodic, structured, alkaline, reddish clay subsoil, containing soft carbonates.

**Mollerin Soil Series:** This is a Red Kandosol. It has a hardsetting, reddish brown sand topsoil. At 30 to 80 cm depth it grades to a sodic, massive, alkaline red sandy clay loam. This overlies a red-brown hardpan.

**Nangeenan Soil Series:** This is a Calcic Calcarosol. It has a fluffy, reddish brown loam topsoil. At 30 to 80 cm depth it grades to a sodic, structured, red clay loam. The soil is alkaline and contains soft and nodular carbonates.

**Neening Soil Series:** This is a Calcic Calcarosol. It has a structured, greyish brown sandy clay loam topsoil. At <10 cm depth it grades to a moderately structured, alkaline, grey clay, containing soft and nodular carbonates. The soil cracks when dry.

**Norpa Soil Series:** This is an Orthic Tenosol. It has a neutral pH, greyish brown sand topsoil. At 30 to 80 cm it grades to a massive, acidic, yellowish sandy loam, containing ferruginous gravels below 80 cm.

**Northam-1 Soil Series:** This is a Red Vertosol. It has a structured, red light clay topsoil, grading to a well structured alkaline, reddish clay, containing soft carbonates. This overlies weathered dolerite at >80 cm depth.

**Ulva Soil Series:** This is an Orthic Tenosol. It has a slightly acidic, greyish brown sand loam topsoil, grading to a yellowish brown, acidic, gravelly sandy clay loam. The ferruginous gravels increase with depth to a mottled indurated horizon.
Figure 8. Guide to identifying soils in the field.

KEY TO SOIL SERIES

Ironstone gravel content at < 30 cm deep

< 20% > 20%

Surface texture

Surface condition

Firm Loose (fluffy)

Profile texture

Subsoil structure

Subsoil colour

Clayey

Sandy

Loamy (sandy loam, sandy clay loam)

Sandy or clayey

Loamy or clayey

Subsoil texture

Subsoil colour

Loam grading to clay

Loam over clay

Subsoil pH

Subsoil colour

Greyish

Reddish

Brownish

Yellowish

Overlying

Profile texture

Subsoil pH

Gravels in subsoil

< 20% > 20%

< 30 cm > 30 cm

Clay within profile

Merredin Beacon

Merredin-1

Holleton

Eabbin

Colgar

Nortam-1

Nangeenan

Boree

Korbel

Kora

Collgar-1

Ningiri

Reddish

Greyish

Better than weak

Structureless/weak

Norse Hill

Reddish

Brownish

Yellowish

Overlying

Profile texture

Subsoil pH

Gravels in subsoil

< 20% > 20%

< 7.5 > 7.5

Clay within profile

Merredin Beacon

Merredin-1

Holleton

Eabbin

Colgar

Nortam-1

Nangeenan

Boree

Korbel

Kora

Collgar-1

Ningiri

Reddish

Greyish

Better than weak

Structureless/weak

Norse Hill

Reddish

Brownish

Yellowish

Overlying

Profile texture

Subsoil pH

Gravels in subsoil

< 20% > 20%

< 7.5 > 7.5

Clay within profile

Merredin Beacon

Merredin-1

Holleton

Eabbin

Colgar

Nortam-1

Nangeenan

Boree

Korbel

Kora

Collgar-1

Ningiri

Reddish

Greyish

Better than weak

Structureless/weak

Norse Hill

Reddish

Brownish

Yellowish

Overlying
Granite rock outcrops like this one south-east of Bencubbin are characteristic of the Kwelkan Land System.

Gravelly soils occur in upper parts of the landscape and are frequently excavated for road building in the Yelbeni and Koorda Systems.

The graceful salmon gum is a common tall tree in the Trayning and Muckinbudin Systems which occur in broad, flat valley floors.

Long, sweeping slopes are characteristic of the Nembudding soil-landscape which is dominated by the Booraan Soil Series.

Large salt lakes such as Lake Brown, photographed from Eagle Rock, are a prominent feature of the Wallambin System—wet in winter but dry in summer with large salt crystals on the surface.

Quartz dykes are not common but are prominent in the landscape because they resist weathering.
SP1. Booraan Series or sandy salmon gum soil has texture contrast of sandy loam over clay loam at <30 cm (page 48).

SP2. Hines Hill Series or morrel soil has a fluffy topsoil grading into a reddish brown sandy clay loam subsoil (page 58).

SP3. Norpa Series or deep yellow sandplain covers large areas in the upper landscape. The Holleton and Cunderdin Soil Series look very similar but have different properties which affect management (page 76).

SP4. Collgar Series is known as a duplex soil and has a clayey sand surface overlying a bleached layer (page 50).

SP5. The Merredin Series or salmon gum/gimlet soil is a sandy loam over a reddish clay (page 66).

SP6. Ulva Series is a gravelly sand which occurs in upland positions (page 80).

SP7. The Jura Series is often called a York gum/jam soil and overlies weathered granite (page 62).
Table 5. Distribution of soils series in each system map unit.

<table>
<thead>
<tr>
<th>System soil series</th>
<th>Baladji (ha)</th>
<th>Cleary (ha)</th>
<th>Gabbabin (ha)</th>
<th>Koorda (ha)</th>
<th>Kununoppin (ha)</th>
<th>Kwelkan (ha)</th>
<th>Mungabindin (ha)</th>
<th>Nembudding (ha)</th>
<th>Nungarin (ha)</th>
<th>Trayning (ha)</th>
<th>Wallambin (ha)</th>
<th>Wialki (ha)</th>
<th>Yelbeni (ha)</th>
<th>Yetelling (ha)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>40</td>
<td>60</td>
<td>15</td>
<td>4</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>80,088</td>
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<td>130</td>
<td>60</td>
<td>5</td>
<td>24,761</td>
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<td>Hines Hill</td>
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<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
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<td>130</td>
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<td>130</td>
<td>60</td>
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<td>10</td>
<td>130</td>
<td>60</td>
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<td>40</td>
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<td>60</td>
<td>5</td>
<td>55,170</td>
<td>4</td>
</tr>
<tr>
<td>Nangeenan</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>78,950</td>
<td>5</td>
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<tr>
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<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
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<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>27,525</td>
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<tr>
<td>Norpa</td>
<td>25</td>
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<td>10</td>
<td>2</td>
<td>3</td>
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<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>142,825</td>
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<tr>
<td>Northam-1</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>32,570</td>
<td>2</td>
</tr>
<tr>
<td>Ulva</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
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<td>130</td>
<td>60</td>
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<td>2</td>
<td>3</td>
<td>30</td>
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<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>101,919</td>
<td>7</td>
</tr>
<tr>
<td>Rock outcrops</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>101,919</td>
<td>7</td>
</tr>
<tr>
<td>Salt lakes</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>130</td>
<td>60</td>
<td>5</td>
<td>101,919</td>
<td>7</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>20,100</td>
<td>60,700</td>
<td>8,700</td>
<td>285,600</td>
<td>107,100</td>
<td>72,700</td>
<td>241,300</td>
<td>43,100</td>
<td>96,200</td>
<td>120,800</td>
<td>92,400</td>
<td>166,800</td>
<td>2,900</td>
<td>1,505,700</td>
<td>100</td>
</tr>
<tr>
<td>Area (%)</td>
<td>1</td>
<td>4</td>
<td>0.5</td>
<td>19</td>
<td>7</td>
<td>5</td>
<td>16</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>0.5</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Beacon Soil Series

The Beacon Series is occasionally called a red soil and was first described in this survey. It has a hardsetting surface and a red loam topsoil. At greater than 80 cm it grades to a well structured red clay subsoil with a common abundance of soft carbonates and a few nodular carbonates. It is moderately alkaline at the surface and highly alkaline in the subsoil. The soil is found on the broad valley floors in the north and east of the survey area.

Classification

Australian Soil Classification [Isbell 1995]  Endohypersodic Pedal Calcic Calcarosol
Great Soil Group [Stace et al. 1968]  Calcareous Red Earth
Principal Profile Form [Northcote 1979]  Dr2.13, Gc1, Gc2

Definition

1: Endohypersodic Pedal Calcic Calcarosol
2: loam grading to clay (>30 cm)
3: colluvium and alluvium
4: A1 B2k
5: -
6: sandy loam to loam grading to light clay
7: well drained
8: -

Variant recognised

Beacon-1: <30 cm of loam grading to clay

Reference profiles

MDN0324 [Grealish and Wagnon 1995]
REFBEA1 [McArthur 1991] (Beacon-1)

Characteristic soil properties

- Loam grading to clay
- Alkaline throughout
- Soft carbonate segregations in the subsoil
- Moderately structured subsoil
- Sodic (ESP >15) below 50 cm

Land management characteristics

- Hardsetting surface may cause plant emergence problems
- Subsoil salinity may be a problem
- Very good water-holding capacity
Beacon Soil Series

Profile no. MDN0324
Australian Soil Classification Endohypersodic Pedal Hypocalcic Calcarosol
Location Beacon Rock Road, Mount Marshall Shire
AMG 577674mE, 6634970mN, zone 50
Landform Valley floor on a gently undulating plain
Slope: 1% Aspect: south-east
Parent material Colluvium and alluvium
Surface condition Hardsetting surface and cracks (>5 mm)
Native vegetation Trees: *Eucalyptus salubris* Shrubs: *Exocarpus aphyllus, Acacia colletioides, Acacia* spp. (x3), *Eremophila* spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 6</td>
<td>Dark reddish brown (5YR 3/3) sandy loam; moderate platy structure (20 to 50 mm); rough ped fabric; firm soil strength; pH 8.5; diffuse wavy boundary.</td>
</tr>
<tr>
<td>B21k</td>
<td>6 to 40</td>
<td>Red (2.5YR 4/6) sandy clay loam; moderate subangular blocky structure (20 to 50 mm); rough ped fabric; firm soil strength; few medium calcareous soft segregations; pH 9.0; gradual irregular boundary.</td>
</tr>
<tr>
<td>B22k</td>
<td>40 to 150</td>
<td>Red (2.5YR 4/6) clay loam, sandy; moderate subangular blocky structure; rough ped fabric; very firm soil strength; many coarse calcareous soft segregations; pH 9.5 (75 cm), pH 9.5 (150 cm).</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.94</td>
<td>14.4</td>
<td>14.0</td>
<td>12.3</td>
</tr>
<tr>
<td>25 to 30</td>
<td>0.30</td>
<td>21.6</td>
<td>6.5</td>
<td>9.6</td>
</tr>
<tr>
<td>75 to 80</td>
<td>0.12</td>
<td>28.9</td>
<td>14.0</td>
<td>10.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI mg/g</th>
<th>P HCO3 ppm</th>
<th>K HCO3 ppm</th>
<th>CaCO3 %</th>
<th>CEC NH4Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5</td>
<td>86</td>
<td>220</td>
<td>4</td>
<td>&gt;300</td>
<td>11</td>
<td>4.25a</td>
<td>1.91a 0.97a 0.16a</td>
</tr>
<tr>
<td>25 to 30</td>
<td>54</td>
<td>23</td>
<td>&lt;2</td>
<td>270</td>
<td>&lt;2</td>
<td>10</td>
<td>9.04a 1.84a 0.86a 0.26a</td>
</tr>
<tr>
<td>70 to 80</td>
<td>477</td>
<td>13</td>
<td>&lt;2</td>
<td>&gt;300</td>
<td>8</td>
<td>18</td>
<td>7.54a 5.18c 1.16c 3.30c</td>
</tr>
</tbody>
</table>
Booraan Soil Series

The Booraan Soil Series is commonly called a sandy salmon gum soil. It was first identified in the Merredin survey [Bettenay and Hingston 1961]. It has a hardsetting surface, with a greyish brown to reddish brown sandy loam topsoil. At less than 30 cm there is an abrupt texture contrast with a brown to reddish brown clay loam to clay subsoil containing soft and nodular carbonates. The topsoil is moderately acidic to neutral, the subsoil is alkaline. It is found in all slope positions.

Classification

Australian Soil Classification [Isbell 1995]                                Calcic Hypernatric Brown Sodosol
Great Soil Group [Stace et al. 1968]                                      Solonized Brown Soil
Principal Profile Form [Northcote 1979]                                   Dy3.43

Definition

1: Calcic Hypernatric Brown Sodosol
2: loam over clay at <30 cm
3: colluvium from weathered granite material
4: A1 B2tk
5: -
6: sandy loam over clay loam to medium clay
7: moderately well drained
8: -

Variant recognised

Booraan-1: loam over clay at 30 to 80 cm

Reference profiles

MDN0323 [Grealish and Wagnon 1995]
P295, P296 CSIRO [Hingston and Bettenay 1961]

Characteristic soil properties

- Texture contrast, loam over clay
- Very sodic subsoil (ESP >25)
- Brown subsoil
- Soft and nodular carbonates in subsoil
- Hardsetting surface

Land management characteristics

- Hardsetting surface increases run-off, hampering water entry and seeding
- Good soil water storage
- Soil structure deterioration will reduce soil workability
- Possible waterlogging in very wet periods, depending on landscape position
Booraan Soil Series

Representative profile

Profile no. MDN0323
Australian Soil Classification Calcic Hyperartric Brown Sodosol
Location Marindo North Road, Mount Marshall Shire
AMG 573081mE, 6635775mN, zone 50
Landform Mid to slope on a gently undulating rise.
Slope: 1%  Aspect: east
Parent material Possibly colluvium from pallid horizon and weathered granite
Surface condition Hardsetting
Native vegetation Trees: Eucalyptus salmonophloia  Mallees: E. loxophleba
Shrubs: Exocarpus aphyllus, Acacia colletioides, Eremophila spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 7</td>
<td>Dark brown (7.5YR 3/3) sandy loam; weak subangular blocky structure (&lt;2 mm); rough ped fabric; firm soil strength; pH 7.5; diffuse irregular boundary.</td>
</tr>
<tr>
<td>B21t</td>
<td>7 to 25</td>
<td>Dark brown (7.5YR 3/3) clay loam; sandy, moderate subangular blocky structure (5 to 10 mm); rough ped fabric; firm soil strength; few medium calcareous segregations; pH 8.0; clear wavy boundary.</td>
</tr>
<tr>
<td>B22tk</td>
<td>25 to 70</td>
<td>Strong brown (7.5YR 4/6) clay loam; sandy, moderate angular blocky structure (5 to 10 mm); rough ped fabric; very firm soil strength; abundant very coarse calcareous soft segregations; pH 9.5; clear wavy boundary.</td>
</tr>
<tr>
<td>B23tk</td>
<td>70 to 110</td>
<td>Strong brown (7.5YR 4/6) medium heavy clay; massive structure; earthy fabric; very strong soil strength; many coarse calcareous segregations; pH 9.5.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size %</th>
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<td>0.02</td>
<td>0.05</td>
<td>0.10</td>
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<tr>
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<td>0.84</td>
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<tr>
<td>15 to 20</td>
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<td>23</td>
<td>0.49</td>
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<td>12.9</td>
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<td>20 to 55</td>
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<td>44.3</td>
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<td>90 to 150</td>
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<td>48.7</td>
<td>9.9</td>
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</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
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<th>P</th>
<th>K</th>
<th>HCO₃</th>
<th>CaCO₃</th>
<th>CEC</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
<td>Ca</td>
<td>Mg</td>
<td>Mn</td>
<td>K</td>
<td>Na</td>
<td>Al</td>
</tr>
<tr>
<td>0 to 5</td>
<td>57</td>
<td>28</td>
<td>4</td>
<td>290</td>
<td>8</td>
<td>4.25c</td>
<td>2.71c</td>
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<tr>
<td>15 to 20</td>
<td>78</td>
<td>30</td>
<td>2</td>
<td>&gt;300</td>
<td>&lt;2</td>
<td>27</td>
<td>7.93c</td>
</tr>
<tr>
<td>50 to 55</td>
<td>56</td>
<td>37</td>
<td>&lt;2</td>
<td>&gt;300</td>
<td>18</td>
<td>19</td>
<td>3.56c</td>
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<tr>
<td>90 to 95</td>
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<td>62</td>
<td>&lt;2</td>
<td>&gt;300</td>
<td>&lt;2</td>
<td>22</td>
<td>1.98c</td>
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</table>

49
**Collgar Soil Series**

The Collgar Series is commonly called a duplex soil. It was first identified in the Merredin survey (Bettenay and Hingston 1961). It has a hardsetting surface and a clayey sand topsoil, overlying a massive, indurated, bleached A2 horizon that may contain ferruginous gravels. At 30 to 80 cm depth it grades to a moderately structured, gravelly sandy loam to sandy clay subsoil, with some ferruginous gravels. Impenetrable siliceous pans occur at varying depths in the subsoil. The pH is neutral throughout. This soil occurs on lower footslopes and in upper valley floor positions.

**Classification**

Australian Soil Classification [Isbell 1995] Ferric-Sodic Eutrophic Grey Kandosol
Great Soil Group [Stace et al. 1968] Solonetz
Principal Profile Form [Northcote 1979] Dy3.41

**Definition**

1: Ferric-Sodic Eutrophic Grey Kandosol
2: sand grading to gravelly loam at 30 to 80 cm on hardpan at >80 cm
3: colluvium from granite and laterite
4: A1 A2 B2wc Cqm
5: -
6: loamy medium to coarse sand over gravelly sandy loam
7: moderately well drained
8: -

**Similar soils**

Collgar-1: texture contrast, grey sodic subsoil, no gravels in subsoil
Korbel: reddish loam topsoil, mottled clay loam subsoil

**Variant recognised**

Collgar-3: sand grading to gravelly loam at 30 to 80 cm on hardpan at 30 to 80 cm

**Reference profiles**

MDN0120 [Grealish and Wagnon 1995]
P293 CSIRO [Hingston and Bettenay 1961] (Collgar-3)
P344 CSIRO [Hingston and Bettenay 1961]

**Characteristic soil properties**

- Sand grading to loam
- Greyish subsoil
- >20% ferruginous nodules in subsoil
- Hardpan in the subsoil

**Land management characteristics**

- Position in the landscape (lower slope) and subsoil hardpan make it susceptible to waterlogging
- The hardpan is impenetrable to root penetration, usually below 50 cm
- Good soil water storage due to perching of water above the hardpan
- Fair workability
- Susceptible to wind and water erosion
- Well drained
### Collgar Soil Series

#### Representative profile

**Profile no.** MDN0120  
**Australian Soil Classification** Ferric-Sodic Eutrophic Grey Kandosol  
**Location** Lackman Road  
AMG 545080mE, 6558445mN, zone 50  
**Landform** Valley floor  
Slope: <1%  Aspect: north  
**Parent material** Colluvium  
**Surface condition** Hardsetting  
**Native vegetation**  
*Trees:* *Santalum acuminatum, Eucalyptus loxophleba*  
*Mallees:* *Eucalyptus* spp. (x2)  
*Shrubs:* *Acacia colletioides, Acacia* spp.

#### Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 20</td>
<td>Dark greyish brown (10YR 4/2) clayey sand; firm soil strength; pH 7.0; gradual boundary.</td>
</tr>
<tr>
<td>A2</td>
<td>20 to 70</td>
<td>Grey (10YR 6/1) coarse sandy loam; massive structure; firm soil strength; pH 7.5; gradual boundary.</td>
</tr>
<tr>
<td>B2wc</td>
<td>70 to 100</td>
<td>Pinkish grey (7.5YR 7/2) sandy clay loam; weak subangular blocky structure; very firm soil strength; common medium ferruginous gravels; pH 8.0.</td>
</tr>
<tr>
<td>Cqm</td>
<td>100+</td>
<td>Siliceous hardpan.</td>
</tr>
</tbody>
</table>
**Collgar-1 Soil Series**

The Collgar-1 Series is commonly called a duplex soil. It was first identified in the current survey as a variant of the Collgar Series because of its texture contrast. It has a hardsetting surface, and a clayey sand topsoil, overlying a massive, indurated, bleached A2 horizon. At less than 30 cm depth there is a clear change to a moderately structured, sandy clay to medium clay subsoil, with a hardpan at depth. The soil pH is neutral throughout. It occurs on lower footslopes and in upper valley landscape positions.

**Classification**

- Australian Soil Classification [Isbell 1995]: Eutrophic Hypematric Grey Sodosol
- Great Soil Group [Stace et al. 1968]: Solodic Soil
- Principal Profile Form [Northcote 1979]: Dy3.41

**Definition**

1. Eutrophic Hypematric Grey Sodosol
2. sand over clay at <30 cm on hardpan at >80 cm
3. colluvium from granite and laterite
4. A1 A2 B2t
5. 
6. loamy medium to coarse sand over clay
7. moderately well drained
8. 

**Similar soils**

- Collgar: no texture contrast, gravel in subsoil
- Korbel: loam topsoil, mottled loam subsoil

**Variants recognised**

- Collgar-2: Eutrophic Hypematric Brown Sodosol (brown subsoil)

**Reference profiles**

- MDN0343 [Grealish and Wagnon 1995]
- REFKELL5 [McArthur 1991] (Collgar-2)

**Characteristic soil properties**

- Texture contrast: sand over clay
- Highly sodic (ESP >25) subsoil
- Greyish subsoil
- Hardpan in the subsoil

**Land management characteristics**

- Position in the landscape (lower slope) makes it susceptible to waterlogging
- The hardpan will be impenetrable to root penetration, usually below 50 cm
- Good soil water storage
- Fair workability
- Susceptible to wind and water erosion
LAND RESOURCES OF THE BENCUBBIN AREA

Colgar-1 Soil Series

Representative profile
Profile no. MDN0343
Australian Soil Classification Eutrophic Hypernatric Grey Sodosol
Location AMG 526172mE, 6600104mN, zone 50
Landform Valley floor on a gently undulating plain, in a tributary valley
Slope: <1% Aspect: south-east
Parent material Colluvium and alluvium
Surface condition Hardsetting
Native vegetation Trees: Eucalyptus salubris Mallee: E. loxophleba
Shrubs: Melaleuca spp., Hakea spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 10</td>
<td>Brown (7.5YR 5/2) clayey sand; massive structure; firm soil strength; pH 6.0; clear wavy boundary.</td>
</tr>
<tr>
<td>A2</td>
<td>10 to 20</td>
<td>Pinkish grey (7.5YR 6/2) sandy clay loam; massive structure; firm soil strength; pH 7.5; abrupt wavy boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>20 to 95</td>
<td>Pale brown (10YR 6/3) light medium clay; moderately developed blocky structure; strong soil strength; orange redox and grey mottles increasing with depth from few to abundant; pH 7.5.</td>
</tr>
<tr>
<td>Cm</td>
<td>95+</td>
<td>Hardpan.</td>
</tr>
</tbody>
</table>
**Cunderdin Soil Series**

The Cunderdin Series is commonly called a deep yellow sand and was first noted in the Northam survey (Lantzke and Fulton 1993). It has a yellowish brown sand topsoil. The subsoil is a uniform, massive, porous, yellow medium sand, with a slight increase in clay content to a clayey sand at depth (or sandy loam at greater than 80 cm). The profile is neutral to slightly acidic. It generally occurs in upland positions, but can occasionally be found on upper to mid-slopes.

**Classification**

Australian Soil Classification [Isbell 1995]  Basic Arenic Orthic Tenosol
Great Soil Group [Stace et al. 1968]  Siliceous Sand
Principal Profile Form [Northcote 1979]  Uc5.11, Uc5.22

**Definition**

1: Basic Arenic Orthic Tenosol
2: >80 cm of sand
3: sand from granite
4: A1 B2w

5: -
6: medium to coarse sand grading to clayey sand
7: well drained
8: -

**Similar soils**

Norpa: contains >20% ferruginous gravel in the subsoil
Holleton: acidic

**Variant recognised**

Subsoil texture may grade to sandy loam

**Reference profile**

MDN0277 [Grealish and Wagnon 1995]

**Characteristic soil properties**

- Weak pedological development in the subsoil
- >80 cm of sand
- pH >5.5
- Brownish yellow subsoil

**Land management characteristics**

- No topsoil structure, susceptible to wind erosion
- Traffic pans may develop
- Low water-holding capacity and nutrient content
- Susceptible to subsurface acidification
- Water repellent (non-wetting) surface
Cunderdin Soil Series

Representative profile

Profile no. MDN0277
Australian Soil Classification Basic Arenic Orthic Tenosol
Location Welbungin to Wialki road
AMG 594993mE, 6590781mN, zone 50
Landform Upper slope in upland areas on a gently undulating rise
Slope: 3% Aspect: north-west
Parent material Sandy colluvium from granite
Surface condition Firm surface moderate wind erosion, slight sheet erosion
Native vegetation Mallees: *Eucalyptus oldfieldii*
Shrubs: *Acacia acuminata, Allocasuarina* spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 15</td>
<td>Brown (7.5YR 4/4) sand; massive structure; sandy fabric; weak soil strength; pH 6.0; clear wavy boundary.</td>
</tr>
<tr>
<td>B2</td>
<td>15 to 90</td>
<td>Brownish yellow (10YR 6/6) clayey sand; massive structure; sandy fabric; weak soil strength; very few medium ferruginous concretions; pH 6.0.</td>
</tr>
</tbody>
</table>
Elabbin Soil Series

The Elabbin Series is occasionally called white gum breakaway country. It was first described in the Merredin survey [Bettenay and Hingston 1961]. It has a hardsetting surface, and an acidic, coarse sand to sandy loam topsoil. At less than 30 cm depth it grades to an acidic, gritty sandy clay loam to clay loam subsoil in a range of colours. The profile is generally shallow, merging with kaolinised rock. It is located near the base of breakaways or where pale weathered rock is exposed at the surface.

Classification

Australian Soil Classification [Isbell 1995] Haplic Natric Brown Kurosol
Great Soil Group [Stace et al. 1968] Soloth
Principal Profile Form [Northcote 1979] Dy3.41

Definition

1: Haplic Natric Brown Kurosol
2: sand over clay at <30 cm on saprolite at >80 cm
3: saprolite
4: A1 B2t Cr
5: -
6: coarse sand to sandy loam over stony sandy clay
7: imperfectly drained
8: -

Similar soils

Balkuling Soil Series (Northam survey)

Variant recognised

Elabbin-1: sandy loam over sandy clay loam

Reference profiles

MDN0107 [Grealish and Wagnon 1995] (lighter Elabbin-1)
P341 [Hingston and Bettenay 1961]
REFKELL3 [McArthur 1991]

Characteristic soil properties

- Weak pedological development in the subsoil
- Sand grading to clay at <30 cm
- Subsoil directly overlies partially weathered or decomposed rock
- Acidic subsoil pH <5.5

Land management characteristics

- Highly susceptible to water erosion
- Run-off recharge area
- Very poor (<30 cm) plant rooting depth
- Low soil water storage
- Susceptible to structural degradation
Elabbin Soil Series

Representative profile

<table>
<thead>
<tr>
<th>Profile no.</th>
<th>MDN0107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Soil Classification</td>
<td>Haplic Natric Brown Kurosol</td>
</tr>
<tr>
<td>Location</td>
<td>AMG 617676mE, 6547986mN, zone 50</td>
</tr>
<tr>
<td>Landform</td>
<td>Footslope at the base of a breakaway in an undulating rise</td>
</tr>
<tr>
<td>Slope: 3% Aspect: south-west</td>
<td></td>
</tr>
<tr>
<td>Parent material</td>
<td>Saprolite</td>
</tr>
<tr>
<td>Surface condition</td>
<td>Surface stones, sheet erosion</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>Shrubs: <em>Acacia acuminata</em>, <em>Grevillea paradoxa</em>, <em>Allocasuarina</em> spp.</td>
</tr>
</tbody>
</table>

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 10</td>
<td>Strong brown (7.5YR 4/6) sandy loam; weak subangular blocky (5 to 10 mm) structure; rough ped fabric; firm soil strength; pH 6.0; clear boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>10 to 95</td>
<td>Strong brown (7.5YR 5/6) sandy clay loam; massive structure; firm soil strength; few quartz fragments and many kaolnised rock fragments; pH 5.5; clear irregular boundary.</td>
</tr>
<tr>
<td>Cr</td>
<td>95+</td>
<td>Kaolnised rock.</td>
</tr>
</tbody>
</table>
**Hines Hill Soil Series**

The Hines Hill Series is occasionally called a morrel soil. It was first identified in the Merredin survey [Bettenay and Hingston 1961] but was not well differentiated from the Nangeenan Soil Series. It is a weakly developed soil formed in wind blown material from adjacent salt lakes. It has a very fluffy greyish brown, sandy loam topsoil which grades into a reddish brown sandy clay loam subsoil with depth. The soil is slightly alkaline at the surface becoming strongly alkaline with increasing soft carbonates with depth through the profile.

**Classification**

Australian Soil Classification [Isbell 1995]  Endohypersodic Regolithic Calcic Calcarosol
Great Soil Group [Stace et al. 1968]  Calcareous Brown Earth
Principal Profile Form [Northcote 1979]  Dy1.53

**Definition**

1: Endohypersodic Regolithic Calcic Calcarosol
2: loam
3: aeolian material from adjacent salt lake mixed with alluvium
4: A1 B2k
5: -
6: sandy loam grading to sandy clay loam
7: imperfectly drained
8: -

**Similar soils**

Nangeenan: subsoil is better structured, contains nodular carbonates, has heavier texture and sodic above 50 cm

**Reference profiles**

MDN0328 [Grealish and Wagnon 1995]
P550 CSIRO [Stace et al. 1968, p. 204]

**Characteristic soil properties**

- Alkaline throughout
- Loam texture
- Soft carbonate segregation in the subsoil
- Highly sodic (ESP >25) below 50 cm
- Loose fluffy surface

**Land management characteristics**

- Salt crusting can occur on the surface
- May have a high watertable
- Highly susceptible to structural degradation, surface will seal
- Loose fluffy surface, susceptible to wind erosion
- Soil water limited to most plants because of the osmotic effects due to the high concentration of soluble salts in the soil solution

58
Hines Hill Soil Series

Representative profile
Profile no
MDN0328
Australian Soil Classification
Endohypersodic Regolithic Calcic Calcarosol
Location
McAndrew Road, Trayning Shire
AMG 560963mE, 6571848mN, zone 50
Landform
Footslope on level plain, about 50 m from the edge of a salt lake plain
Slope: 1% Aspect: north-east
Parent material
Colluvium and aeolian material from adjacent salt lakes
Surface condition
Loose surface (fluffy)
Native vegetation
Trees: *Callitris* sp. Shrubs: *Allocasuarina* spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11</td>
<td>0 to 15</td>
<td>Dark brown (7.5YR 3/4) sandy loam; weak angular blocky (20 to 50 mm) structure; rough ped fabric; weak soil strength; pH 8.0; abrupt irregular boundary.</td>
</tr>
<tr>
<td>A12</td>
<td>15 to 50</td>
<td>Yellowish red (5YR 4/6) sandy loam; weak angular blocky (20 to 50 mm); rough ped fabric; weak soil strength; few calcareous soft segregations; pH 9.0; abrupt wavy boundary.</td>
</tr>
<tr>
<td>B2</td>
<td>50 to 80</td>
<td>Reddish brown (5YR 4/6) fine sandy clay loam; massive structure; sandy fabric; very weak soil strength; few calcareous soft segregations; pH 9.0; abrupt wavy boundary.</td>
</tr>
<tr>
<td>B2k</td>
<td>80 to 120</td>
<td>Reddish brown (5YR 4/6) fine sandy loam; massive structure; sandy fabric; very weak soil strength; common calcareous soft segregations; pH 9.5.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C W/B</th>
<th>Particle size %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:5</td>
<td>1:5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 to 35</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 to 70</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 to 105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>Sample</th>
<th>P</th>
<th>P PRI</th>
<th>P HCO₃</th>
<th>K HCO₃</th>
<th>CaCO₃</th>
<th>CEC NH₄Cl</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:1</td>
<td>1:5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>118</td>
<td>77.2</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>5.88c 0.38c 0.06c 0.06c 0.77c 0.64c 0.06c</td>
</tr>
<tr>
<td>30 to 35</td>
<td>62</td>
<td>11</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>5.46c 0.77c 0.64c 0.06c</td>
</tr>
<tr>
<td>65 to 70</td>
<td>59</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>5.38c 1.38c 0.77c 0.21c</td>
</tr>
<tr>
<td>100 to 105</td>
<td>50</td>
<td>9.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>2.35c 1.77c 0.64c 0.21c</td>
</tr>
</tbody>
</table>
**Holleton Soil Series**

The Holleton Series is occasionally called wodjil soil, named after its characteristic wodjil (acacia) vegetation. It was first identified in the Northam survey [Lantzke and Fulton 1993]. It has a greyish brown, sand to clayey sand topsoil. At less than 30 cm it grades to a yellow massive sand to sandy clay loam subsoil. The soil is very acidic throughout. It occurs in upper to mid-slope landscape positions in upland areas.

**Classification**

Australian Soil Classification [Isbell 1995]  
Great Soil Group [Stace et al. 1968]  
Principal Profile Form [Northcote 1979]

- Acidic Regolithic Orthic Tenosol  
- Yellow Earth  
- Uc5.22, Gn2.61, Gn2.21

**Definition**

1: Acidic Regolithic Orthic Tenosol  
2: sand grading to loam at <30 cm  
3: lateritic sand from granite  
4: A1 B2w  
5:  
6: medium to coarse sand grading to sandy loam  
7: well to rapidly drained  
8: -

**Similar soils**

- Norpa: less acidic, contains >20% ferruginous gravel in subsoil  
- Cunderdin: sand throughout, neutral to slightly acidic

**Reference profile**

- MDN0322 [Grealish and Wagnon 1995]  
- REFBEA3 [McArthur 1991]

**Characteristic soil properties**

- Weak pedological development in the subsoil  
- Sand grading to sandy loam at <30 cm depth  
- Most subsoil pH <5.5  
- Yellowish subsoil  
- Massive structure

**Land management characteristics**

- Highly acidic  
- Low water-holding capacity  
- Low nutrient retention, deficient in major and minor elements  
- Wind erosion risk is high in summer and autumn when vegetative cover is limited  
- May be susceptible to water repellence  
- Well drained
Holleton Soil Series

Representative profile
Profile no. MDN0322
Australian Soil Classification Acidic Regolithic Orthic Tenosol
Location Beacon Rock Road, Mount Marshall Shire
AMG 572400mE, 6635080mN, zone 50
Landform Mid-slope on a gently undulating rise in upland areas
Slope: 2% Aspect: east
Parent material Lateritic sand from granite
Surface condition Water repellent, slight sheet and wind erosion
Native vegetation Mallees: Eucalyptus spp., Acacia spp., Allocasuarina spp., Baeckia spp., Hakea coriacea

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 3</td>
<td>Very dark greyish brown (10YR 3/2) loamy sand; massive structure; weak soil strength; sandy fabric; pH 6.5; water repellent; clear wavy boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>3 to 20</td>
<td>Dark yellowish brown (10YR 4/4) loamy sand; massive structure; weak soil strength; sandy fabric; pH 5.0; water repellent; diffuse irregular boundary.</td>
</tr>
<tr>
<td>B2w</td>
<td>20 to 220</td>
<td>Brownish yellow (10YR 6/6) sandy loam; very few medium distinct redox mottles; massive structure; firm soil strength; sandy fabric; pH 4.5 (50 cm), pH 4.5 (100 cm), pH 6.0 (220 cm).</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH 1:5</th>
<th>EC 1:5</th>
<th>Al mmol/L</th>
<th>Org C %</th>
<th>Particle size %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/B 0.002</td>
<td>to 0.02</td>
<td>to 0.075</td>
<td>to 0.106</td>
<td>to 0.15</td>
</tr>
<tr>
<td>0 to 3</td>
<td>4.8</td>
<td>4.5</td>
<td>29</td>
<td>3</td>
<td>1.46</td>
</tr>
<tr>
<td>10 to 15</td>
<td>4.7</td>
<td>4.1</td>
<td>5</td>
<td>13</td>
<td>0.78</td>
</tr>
<tr>
<td>50 to 55</td>
<td>4.1</td>
<td>3.8</td>
<td>5</td>
<td>34</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>Total P ppm</th>
<th>PRI (mg/g)</th>
<th>P HCO₃ ppm</th>
<th>K HCO₃ ppm</th>
<th>CaCO₃ %</th>
<th>CEC NH₄Cl meq/100g</th>
<th>Exchangeable cations meq/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 3</td>
<td>57</td>
<td>28</td>
<td>&lt;2</td>
<td>4</td>
<td>210</td>
<td>0.48b 1.64b 0.73b 0.03b 0.43b 0.29b</td>
<td></td>
</tr>
<tr>
<td>10 to 15</td>
<td>33</td>
<td>32</td>
<td>&lt;2</td>
<td>23</td>
<td>105</td>
<td>0.64b 0.38b 0.13b &lt;0.02 0.04b 0.04b</td>
<td></td>
</tr>
<tr>
<td>50 to 55</td>
<td>27</td>
<td>200</td>
<td>&lt;2</td>
<td>13</td>
<td>1.04b</td>
<td>0.19b 0.10b &lt;0.02 0.03b &lt;0.02</td>
<td></td>
</tr>
</tbody>
</table>
Jura Soil Series

The Jura Series is formed in weathered granite associated with exposed rock outcrops. It is commonly called a York gum/jam soil. The soil was first identified in the Merredin survey [Bettenay and Hingston 1961]. It has a reddish brown, gritty loamy sand topsoil grading to a gritty sandy loam to sandy clay loam subsoil at less than 30 cm depth, with weak structure. Soil depth and development vary greatly, generally becoming deeper and more developed with distance from exposed granite outcrops. Quartz gravel and feldspar fragments are present. It overlies weathered granite rock at 30 to 80 cm.

Classification
Australian Soil Classification [Isbell 1995]  Sodic Eutrophic Red Kandosol
Great Soil Group [Stace et al. 1968]  Red Earth
Principal Profile Form [Northcote 1979]  Dr4.52/.62/.72, Dy2.13 gradational soil

Definition
1: Sodic Eutrophic Red Kandosol
2: sand grading to loam at <30 cm on weathered granite at 30 to 80 cm
3: weathering from granite rock
4: A1 B2w Cr
5: -
6: loamy sand grading to a sandy loam on weathered granite
7: moderately well drained
8: -

Reference profiles
MDN0316 [Grealish and Wagnon 1995]
P322 [Hingston and Bettenay 1961]

Characteristic soil properties
- Massive to weak subsoil structure
- Sand grading to loam on rock
- Reddish subsoil
- High base status
- Quartz and feldspar fragments present

Land management characteristics
- Recharge area for groundwater
- Associated with surface stones, rocks and outcrops; cultivation may be difficult
- Erodable; gully erosion where surface water is concentrated
- Good plant rooting depth
- Low soil water storage
Jura Soil Series

Representative profile
Profile no. MDN0316
Australian Soil Classification Sodic Eutrophic Red Kandosol
Location Walker Road 3 km east of Gillet
AMG 593846mE, 66011434mN, zone 50
Landform Mid-slope on an undulating low hill, 800 m below a granite outcrop
Slope: 2%  Aspect: west
Parent material Weathered granite
Surface condition Loose soil surface
Native vegetation Mallees: *Eucalyptus loxophleba, Calycopeplus ephedroides*
Shrubs: *Grevillea paniculata, Acacia acuminata, Acacia spp.*

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11</td>
<td>0 to 10</td>
<td>Dark red (2.5YR 3/6) loamy coarse sand; massive structure; weak soil strength; pH 6.0; clear wavy boundary.</td>
</tr>
<tr>
<td>A12</td>
<td>10 to 30</td>
<td>Red (2.5YR 4/6) clayey sand; massive structure; weak soil strength; pH 5.5; clear wavy boundary.</td>
</tr>
<tr>
<td>B2w</td>
<td>30 to 50</td>
<td>Red (10R 4/8) sandy loam; weak structure; firm soil strength; pH 6.0; gradual boundary.</td>
</tr>
<tr>
<td>Cr</td>
<td>50+</td>
<td>Red (10R 4/8) sandy loam with abundant decomposed granite fragments.</td>
</tr>
</tbody>
</table>
Korbel Soil Series

The Korbel Series was first named in the Merredin survey [Bettenay and Hingston 1961]. It has a hardsetting surface, a dark reddish brown sandy loam topsoil grading to a reddish brown clay loam subsoil at 30 to 80 cm, with yellow and grey mottles. An indurated layer occurs below this.

Classification

Australian Soil Classification [Isbell 1995]  Mottled Eutrophic Red Kandosol
Great Soil Group [Stace et al. 1968]  Solodized Solonetz
Principal Profile Form [Northcote 1979]  Dr3.72

Definition

1: Mottled Eutrophic Red Kandosol
2: loam >80 cm
3: colluvium
4: A1 B2w Cqm
5: -
6: Sandy loam grading to sandy clay loam to sandy clay
7: imperfectly drained
8: -

Similar soils

Collgar: sandy topsoil and grey subsoil

Variant recognised

Korbel-1: Mesotrophic Mottled-Subnatric Red Sodosol, sand over clay at 30 to 80 cm on a hardpan >80 cm, A1 B2t Cm.

Reference profiles

MDN0326 [Grealish and Wagnon 1995] (Korbel-1)
P374 [Hingston and Bettenay 1961]

Characteristic soil properties

• Sandy loam grading to clay loam
• Reddish subsoil
• Mottled subsoil
• High base status (>15%)
• Hardpan in subsoil

Land management characteristics

• Susceptible to waterlogging depending on depth to clay or hardpan
• Good soil water storage
• Good workability
• Susceptible to wind erosion
• Highly susceptible to subsoil compaction
### Korbel-1 Soil Series

**Representative profile**

<table>
<thead>
<tr>
<th>Profile no.</th>
<th>MDN0326</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Soil</td>
<td>Mesotrophic Mottled-Subnatric Red Sodosol</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>McAndrew Road, Trayning Shire AMG 559324mE, 6564480mN, zone 50</td>
</tr>
<tr>
<td>Landform</td>
<td>Footslope on a gently undulating plain in the valley floor Slope: 1% Aspect: south-east</td>
</tr>
<tr>
<td>Parent material</td>
<td>Colluvium</td>
</tr>
<tr>
<td>Surface condition</td>
<td>Hardsetting</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>Mallees: <em>Eucalyptus</em> spp.</td>
</tr>
</tbody>
</table>

**Morphological description**

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 12</td>
<td>Greyish brown (10YR 5/2) sandy loam; massive structure; sandy fabric; pH 6.0; sharp wavy boundary.</td>
</tr>
<tr>
<td>A2</td>
<td>12 to 55</td>
<td>Very pale brown (10YR 7/4) clayey sand; very few fine faint reddish yellow mottles; massive structure; sandy fabric; pH 7.5; sharp wavy boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>55 to 80</td>
<td>Reddish yellow (5YR 7/8) sandy clay; many medium distinct red mottles; massive structure; sandy ped fabric; pH 7.0; sharp wavy boundary.</td>
</tr>
<tr>
<td>Cm</td>
<td>80+</td>
<td>Indurated hardpan.</td>
</tr>
</tbody>
</table>

**Chemical and physical analysis (<2 mm fraction)**

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H_2O 1:5</td>
<td>Ca2+ 1:5</td>
<td>m/m</td>
<td>ppm</td>
<td>W/B</td>
</tr>
<tr>
<td>0 to 5</td>
<td>5.5</td>
<td>4.6</td>
<td>4</td>
<td>2</td>
<td>0.98</td>
</tr>
<tr>
<td>30 to 35</td>
<td>6.6</td>
<td>6.0</td>
<td>2</td>
<td>1.14</td>
<td>4.0</td>
</tr>
<tr>
<td>70 to 75</td>
<td>6.4</td>
<td>5.2</td>
<td>1</td>
<td>0.98</td>
<td>37.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI mL/g</th>
<th>P HCO_3 ppm</th>
<th>K HCO_3 ppm</th>
<th>CaCO_3 %</th>
<th>CEC NH_4Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Al Ca Mg Mn K Na</td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>85</td>
<td>3.8</td>
<td>13</td>
<td>30</td>
<td>0.24b</td>
<td>1.30b</td>
<td>0.23b</td>
</tr>
<tr>
<td>30 to 35</td>
<td>24</td>
<td>2.3</td>
<td>2</td>
<td>12</td>
<td>&lt;0.02</td>
<td>0.57b</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>70 to 75</td>
<td>30</td>
<td>6.4</td>
<td>&lt;2</td>
<td>82</td>
<td>&lt;0.02</td>
<td>1.28b</td>
<td>3.10b</td>
</tr>
</tbody>
</table>
Merredin Soil Series

The Merredin Series is commonly known as a salmon gum/gimlet soil. It was first identified in the Cleary survey [Teakle 1936] and later in the Merredin survey [Bettenay and Hingston 1961]. It has a hardsetting surface, and a sandy clay loam to loam topsoil. At less than 30 cm depth it grades to a reddish brown to yellowish red, structured clay subsoil, with soft and nodular carbonates. The surface is neutral becoming strongly alkaline in the subsoil. It may become acidic at depth (>150 cm). The soil surface cracks in summer. It occurs on valley floors and is often associated with gilgai surface relief.

Classification

Australian Soil Classification [Isbell 1995]  
Great Soil Group [Stace et al. 1968]  
Principal Profile Form [Northcote 1979]  
Epihypersodic Pedal Calcic Calcarosol  
Solonized Brown Soil  
Dr2.53, Dr2.63, Dy2.63

Definition

1: Epihypersodic Pedal Calcic Calcarosol  
2: loam grading to clay at <30 cm  
3: colluvium and alluvium  
4: A1 B2tk  
5: -  
6: sandy clay loam grading to light to medium clay  
7: moderately well drained  
8: -

Similar soils

Merredin-1: texture contrast, sandy loam over clay, sodic

Reference profiles

MDN0369 [Grealish and Wagnon 1995]  
P343, P348 CSIRO [Hingston and Bettenay 1961]  
P548 [Stace et al. 1968, p. 206]  
REFMER2 [McArthur 1991]

Characteristic soil properties

- Alkaline throughout  
- Loam grading to clay  
- Soft and nodular carbonate segregations in the subsoil  
- Highly sodic below 50 cm

Land management characteristics

- Topsoil structure deteriorates but may be improved with gypsum application (test required)  
- Gilgai microrelief concentrates drainage water  
- Occasionally becomes saline depending on underlying geology and valley position  
- Good soil water storage
Merredin Soil Series

Representative profile

Profile no. MDN0369
Australian Soil Classification Epihypersodic Pedal Calcic Calcarosol
Location Kuljia to Koorda road
AMG 534892mE, 6609344mN, zone 50
Landform Valley plain
Slope: <1% Aspect: south
Parent material Alluvium
Surface condition Hardsetting
Native vegetation Shrubs: *Acacia acuminata*, *A. ligulata*

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 20</td>
<td>Brown (7.5YR 4/4) sandy loam; firm soil strength; pH 6.0; gradual wavy boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>20 to 60</td>
<td>Yellowish red (5YR 5/6) sandy clay loam; firm soil strength; pH 8.0; gradual wavy boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>60 to 85</td>
<td>Reddish yellow (5YR 6/6) light medium clay; moderate subangular blocky (20 to 50 cm) structure; very firm soil strength; few calcareous soft segregations; pH 8.5; gradual wavy boundary.</td>
</tr>
<tr>
<td>B2tk</td>
<td>85 to 95</td>
<td>Reddish yellow (5YR 6/6) light medium clay; weak subangular blocky structure; very firm soil strength; many medium calcareous nodules and soft segregations; pH 9.0.</td>
</tr>
</tbody>
</table>
Merredin-1 Soil Series

The Merredin-1 Series is commonly known as a salmon gum/gimlet soil. It differs from the Merredin Series by having a texture contrast and is not calcareous throughout the profile. It was first separated in the Bencubbin survey [Grealish and Wagnon 1995]. It has a hardsetting surface and a reddish brown, sandy loam topsoil. At less than 30 cm depth it overlies a reddish structured clay subsoil, with soft and nodular carbonates. The surface is neutral becoming strongly alkaline in the subsoil. The soil cracks when dry.

Classification
Australian Soil Classification [Isbell 1995]  
Calcic Subnatric Red Sodosol  
Great Soil Group [Stace et al. 1968]  
Solonized Brown Soil  
Principal Profile Form [Northcote 1979]  
Dr2.53, Dr2.63, Dy2.63

Definition
1:  Calcic Subnatric Red Sodosol  
2:  <30 cm of loam over clay  
3:  colluvium and alluvium  
4:  A1 B2tk

5:  -  
6:  sandy loam over light to medium clay  
7:  moderately well drained  
8:  -

Similar soil
Merredin:  sandy clay loam grading to clay, calcareous throughout

Variant recognised
Merredin-2:  Brown Sodosol

Reference profiles
MDN0331 [Grealish and Wagnon 1995]  
P288 CSIRO [Hingston and Bettenay 1961] (Merredin-2)  

Characteristic soil properties
- Texture contrast, loam over clay  
- Highly sodic subsoil  
- Red subsoil  
- Soft and nodular carbonates in subsoil  
- Hardsetting surface

Land management characteristics
- Hardsetting surface  
- Occasionally becomes saline depending on underlying geology and valley position  
- Low surface relief can lead to surface ponding of water  
- Good soil water storage
Representative profile
Profile no. MDN0331
Australian Soil Classification Calcic Subnatric Red Sodosol
Location McAndrew Road, Trayning Shire
AMG 561391mE, 6565621mN, zone 50
Landform Footslope of a gently undulating plain that is part of a tributary valley
Slope: <1% Aspect: west
Parent material Colluvium and alluvium
Surface condition Hardsetting
Native vegetation Trees: *Eucalyptus salmonophloia, E. salubris*

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 10</td>
<td>Very dark greyish brown (10YR 3/2) sandy loam; weak angular blocky (200 to 500 mm) structure; rough-ped fabric; very firm; pH 7.0; sharp smooth boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>10 to 35</td>
<td>Yellowish red (5YR 4/6); light medium clay; weak subangular blocky (20 to 50 mm) structure; smooth-ped fabric; very firm soil strength; few calcareous soft segregations; pH 9.0; gradual irregular boundary.</td>
</tr>
<tr>
<td>B2tk</td>
<td>35 to 85+</td>
<td>Yellowish red (5YR 5/6) light medium clay; weak subangular blocky (20 to 50 mm) structure; smooth-ped fabric; very firm soil strength; many very coarse calcareous nodules; pH 9.5.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size %</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 0.002</td>
<td>0.001 - 0.02</td>
</tr>
<tr>
<td>0 to 5</td>
<td>6.6</td>
<td>6.0</td>
<td>7</td>
<td>0.81</td>
<td>12.2</td>
<td>8.1</td>
</tr>
<tr>
<td>20 to 25</td>
<td>8.3</td>
<td>7.5</td>
<td>17</td>
<td>0.31</td>
<td>36.6</td>
<td>9.4</td>
</tr>
<tr>
<td>60 to 65</td>
<td>9.3</td>
<td>8.4</td>
<td>85</td>
<td>0.17</td>
<td>39.6</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI ml/g</th>
<th>P HCO₃ ppm</th>
<th>K HCO₃ ppm</th>
<th>CaCO₃ %</th>
<th>CEC NH₄Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>180</td>
<td>9.8</td>
<td>26</td>
<td>240</td>
<td>0.02b</td>
<td>0.76b</td>
<td>0.37b</td>
</tr>
<tr>
<td>20 to 25</td>
<td>54</td>
<td>3</td>
<td>300</td>
<td>&lt;2</td>
<td>16</td>
<td>6.56c</td>
<td>3.72c</td>
</tr>
<tr>
<td>60 to 65</td>
<td>53</td>
<td>43</td>
<td>3</td>
<td>&gt;300</td>
<td>10</td>
<td>2.73c</td>
<td>5.99c</td>
</tr>
</tbody>
</table>

Merredin-1 Soil Series
Mollerin Soil Series

Mollerin Series is commonly called a red-brown hardpan soil. It was first described in the Cleary survey [Teakle 1936]. The soil has a hardsetting surface and a reddish brown, loamy sand topsoil, grading to a massive red sandy loam at 30 to 80 cm depth, which overlies a continuous red-brown hardpan. The topsoil is non-calcareous, but it becomes strongly alkaline in the subsoil. It is found in footslope and valley floor positions.

Classification

Australian Soil Classification [Isbell 1995]  
Sodic Duric Red Kandosol

Great Soil Group [Stace et al. 1968]  
Red and Brown Hardpan Soil

Principal Profile Form [Northcote 1979]  
Gn2.13

Definition

1: Sodic Duric Red Kandosol
2: sand grading to loam over a red brown hardpan at 30 to 80 cm
3: colluvium and alluvium from granite and laterite
4: A1 B2w Cm
5: -
6: loamy sand grading to sandy loam
7: moderately well drained
8: -

Variant

Red-brown hardpan at <30 cm depth

Reference profiles

MDN0468 [Grealish and Wagnon 1995]
REFBEA2 [McArthur 1991]

Characteristic soil properties

- Sand grading to sandy loam
- Reddish subsoil
- Red-brown hardpan below the subsoil
- Sodic subsoil

Land management characteristics

- The subsoil hardpan is impenetrable to plant roots
- Hardsetting surface may hinder seedling emergence
- Waterlogging is a problem after heavy rains for soils with shallow depth to hardpan
- Susceptible to wind erosion
- Low soil water storage
Mollerin Soil Series

Representative profile

Profile no. MDN0468
Australian Soil Classification Sodic Duric Red Kandosol
Location AMG 548182mE, 6643937mN, zone 50
Landform Valley floor on a gently undulating plain
Slope: <1% Aspect: west
Parent material Colluvium and alluvium
Surface condition Hardsetting surface, slight wind erosion, slight scalding
Native vegetation Trees: Eucalyptus salmonophloia
Shrubs: Atriplex spp., Melaleuca spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 45</td>
<td>Dark red (2.5YR 3/6) clayey sand; single grain structure; loose soil strength; pH 6.0; clear wavy boundary.</td>
</tr>
<tr>
<td>B2w</td>
<td>45 to 50</td>
<td>Red (2.5YR 4/6) sandy loam; massive structure; weak soil strength; pH 8.5; very few fine calcareous soft segregations; abrupt smooth boundary.</td>
</tr>
<tr>
<td>Cm</td>
<td>50+</td>
<td>Red-brown hardpan; not penetrable.</td>
</tr>
</tbody>
</table>
**Nangeenan Soil Series**

The Nangeenan Series is commonly called a morrel soil. It was first described in the Merredin survey [Bettenay and Hingston 1961]. It has a loose and fluffy surface when dry, and forms a surface seal when wet. The topsoil is a brown loam containing soft carbonates, which grades at 30 to 80 cm depth to a moderately well structured, red clay loam to light clay subsoil, with 2 to 20% soft carbonates and up to 20% nodular carbonates. The soil is formed in parna sheets that surround salt lakes and main drainage channels.

**Classification**

Australian Soil Classification [Isbell 1995]  
Great Soil Group [Stace et al. 1968]  
Principal Profile Form [Northcote 1979]  

<table>
<thead>
<tr>
<th>Classification</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epiphysodic Pedal Calcic Calcarosol</td>
<td>Epihypersodic Pedal Calcic Calcarosol</td>
</tr>
<tr>
<td>Red Calcareous Soil</td>
<td>30 to 80 cm of loam grading to clay</td>
</tr>
<tr>
<td>Gc1.22</td>
<td>aeolian material from adjacent salt lakes mixed with colluvium and alluvium</td>
</tr>
<tr>
<td>A1 B2k</td>
<td>moderately well drained</td>
</tr>
</tbody>
</table>

**Similar soils**

Hines Hill: structureless subsoil, no nodules, lighter textured, sodic below 50 cm

**Variants recognised**

Nangeenan-1: Epihypersodic Pedal Hypercalcic Calcarosol (>20% soft carbonate and up to 20% nodular carbonates)  
Nangeenan-2: Haplic Pedal Calcic Calcarosol

**Reference profiles**

MDN0327 [Grealish and Wagnon 1995] (Nangeenan-1)  
P289, P290 CSIRO [Hingston and Bettenay 1961]  
REFKELL9 [McArthur 1991] (Nangeenan-2)

**Characteristic soil properties**

- Alkaline throughout  
- Loam grading to clay  
- Soft and nodular carbonate segregations in the subsoil  
- Highly sodic (ESP >15) in the subsoil above 50 cm (not for Nangeenan-2)  
- Loose fluffy surface

**Land management characteristics**

- High salt content, salt scalding  
- Poor topsoil structure; easily wind-blown, and seals when wet  
- Soil water storage is limited by the osmotic effects of high soluble salt concentration in the soil solution
Nangeenan Soil Series

Representative profile

Profile no. MDN0327
Australian Soil Classification Epihypersodic Pedal Hypocalcic Calcarosol
Location McAndrew Road, Trayning Shire
Landform Lower slope on a gently undulating plain in the valley floor
Slope: 3% Aspect: north-east
Parent material Aeolian material from adjacent salt lakes mixed with alluvium and colluvium
Surface condition Loose surface, seals when wet
Native vegetation Trees: Eucalyptus longicornis, E. salubris

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 6</td>
<td>Dark reddish brown (5YR 3/2) sandy loam; weak angular blocky (5 to 10 mm) structure; rough ped fabric; very weak soil strength; pH 9.5; diffuse boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>6 to 32</td>
<td>Reddish brown (5YR 4/4) loam; weak angular blocky (5 to 10 mm) structure; rough ped fabric; firm soil strength; few calcareous soft segregations; pH 9.5; diffuse boundary.</td>
</tr>
<tr>
<td>B2k</td>
<td>32 to 80+</td>
<td>Yellowish red (5YR 5/6) light clay; moderate angular blocky (5 to 10 mm) structure; smooth ped fabric; very firm soil strength; common coarse soft and nodular carbonates; pH 9.5.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H2O</td>
<td>CaCO3</td>
<td>m/m</td>
<td>CaO ppm</td>
<td>W/B %</td>
</tr>
<tr>
<td>0 to 5</td>
<td>8.4</td>
<td>7.6</td>
<td>18</td>
<td>1.61</td>
<td>15.4</td>
</tr>
<tr>
<td>30 to 35</td>
<td>8.5</td>
<td>8.2</td>
<td>470</td>
<td>0.47</td>
<td>27.3</td>
</tr>
<tr>
<td>70 to 75</td>
<td>8.9</td>
<td>8.4</td>
<td>330</td>
<td>0.18</td>
<td>36.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI ml/g</th>
<th>P HCO3 ppm</th>
<th>K HCO3 ppm</th>
<th>CaCO3 %</th>
<th>CEC NH4Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
<td>Ca</td>
<td>Mg</td>
<td>Mn</td>
<td>K</td>
<td>Na</td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>250</td>
<td>19</td>
<td>22</td>
<td>28c</td>
<td>3.0c</td>
<td>0.28c</td>
<td></td>
</tr>
<tr>
<td>30 to 35</td>
<td>120</td>
<td>140</td>
<td>4</td>
<td>&gt;300</td>
<td>19</td>
<td>22</td>
<td>8.4c</td>
</tr>
<tr>
<td>70 to 75</td>
<td>75</td>
<td>86</td>
<td>2</td>
<td>&gt;300</td>
<td>30</td>
<td>20</td>
<td>3.62c</td>
</tr>
</tbody>
</table>
Neening Soil Series

The Neening Series is occasionally referred to as grey clay valley soil. It was first identified in the Merredin survey [Bettenay and Hingston 1961]. Surface cracks are common when dry. It has a well structured, greyish brown, neutral to alkaline, sandy clay loam topsoil. At less than 30 cm depth and commonly less than 10 cm, it grades to a well structured, greyish clay subsoil, containing soft and nodular carbonates. The soil occurs on valley floors.

Classification
Australian Soil Classification [Isbell 1995]         Vertic Pedal Calcic Calcarosol
Great Soil Group [Stace et al. 1968]                Solonized Brown Soil
Principal Profile Form [Northcote 1979]             Um1.3, Ug5.22

Definition
1: Vertic Pedal Calcic Calcarosol
2: clay >80 cm
3: colluvium and some alluvium
4: A1 B2k
5: -
6: sandy clay loam over medium clay
7: imperfectly drained
8: -

Reference profile
MDN0332 [Grealish and Wagnon 1995]

Characteristic soil properties
- Clay texture
- Cracks when dry
- Greyish subsoil
- Strong soil structure
- Alkaline pH throughout

Land management characteristics
- Good topsoil structure, but difficult to work depending on soil moisture conditions
- Susceptible to structural degradation
- Good soil water storage
Neening Soil Series

Representative profile
Profile no. MDN0332
Australian Soil Classification Vertic Pedal Calcic Calcarosol
Location McAndrew Road, Trayning Shire AMG 561067mE, 6566554mN, zone 50
Landform Valley floor of a gently undulating plain, part of a tributary valley Slope: <1% Aspect: east
Parent material Colluvium and alluvium
Surface condition Surface cracks
Native vegetation Trees: *Eucalyptus salubris*

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 15</td>
<td>Dark greyish brown (10YR 4/2) clay loam; strong subangular blocky (20 to 50 mm) structure; smooth ped fabric; firm soil strength; pH 8.5; gradual smooth boundary.</td>
</tr>
<tr>
<td>B2t</td>
<td>15 to 40</td>
<td>Dark greyish brown (10YR 4/2) medium clay; strong angular blocky (20 to 50 mm) structure; smooth ped fabric; very firm soil strength; pH 9.5; diffuse boundary.</td>
</tr>
<tr>
<td>B2tk</td>
<td>40 to 60</td>
<td>Brown (7.5YR 5/4) medium clay; strong angular blocky (20 to 50 mm) structure; smooth ped fabric; very strong soil strength; common calcareous soft and nodular segregations.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>W/B</th>
<th>Organic C</th>
<th>Particle size (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H₂O</td>
<td>CaCl₂</td>
<td>W/B</td>
<td>Organ C</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>0 to 5</td>
<td>8.2</td>
<td>7.6</td>
<td>15</td>
<td>1.14</td>
<td>31.6</td>
</tr>
<tr>
<td>20 to 25</td>
<td>8.4</td>
<td>7.8</td>
<td>23</td>
<td>0.32</td>
<td>41.1</td>
</tr>
<tr>
<td>45 to 50</td>
<td>8.7</td>
<td>8.1</td>
<td>34</td>
<td>0.23</td>
<td>42.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI ml/g</th>
<th>P HCO₃ ppm</th>
<th>K HCO₃ ppm</th>
<th>CaCO₃ %</th>
<th>CEC NH₄Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
<td>Ca</td>
<td>Mg</td>
<td>Mn</td>
<td>K</td>
<td>Na</td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>300</td>
<td>22</td>
<td>71</td>
<td>&gt;300</td>
<td>&lt;2</td>
<td>22</td>
<td>15.0c</td>
</tr>
<tr>
<td>20 to 25</td>
<td>74</td>
<td>64</td>
<td>7</td>
<td>120</td>
<td>&lt;2</td>
<td>25</td>
<td>14.16c</td>
</tr>
<tr>
<td>45 to 50</td>
<td>56</td>
<td>82</td>
<td>4</td>
<td>96</td>
<td>2</td>
<td>22</td>
<td>9.16c</td>
</tr>
</tbody>
</table>
**Norpa Soil Series**

The Norpa Series is commonly known as deep yellow sandplain. It was first identified in the Merredin survey [Bettenay and Hingston 1961]. It has a greyish brown, loamy sand topsoil, grading to a yellow sandy loam subsoil at 30 to 80 cm. Below 80 cm it overlies a ferruginous gravel horizon. The soil is near neutral at the surface, becoming moderately acidic with depth. It occurs in the upland drainage divide areas and upper slopes.

**Classification**

Australian Soil Classification [Isbell 1995]  Acidic Regolithic Orthic Tenosol
Great Soil Group [Stace et al. 1968]  Earthy Sand
Principal Profile Form [Northcote 1979]  Uc5.22, Gn2.61, Gn2.21

**Definition**

1: Acidic Regolithic Orthic Tenosol  
2: sand grading to loam  
3: lateritic sand from granite  
4: A1 B2w C  
5:  
6: loamy medium to coarse sand grading to gravelly medium sandy loam  
7: well to rapidly drained  
8: -

**Similar soils**

Ulva: ferruginous gravels throughout  
Cunderdin: no gravels, neutral pH  
Holleton: sand, strongly acidic, no gravels

**Variant recognised**

Norpa-1: Basic Regolithic Orthic Tenosol (subsoil pH >5.5)

**Reference profiles**

MDN0330 [Grealish and Wagnon 1995]  
P346 CSIRO [Hingston and Bettenay 1961]  
P549 CSIRO [Stace et al. 1968, p. 48]  
REFKELL1 [McArthur 1991] (Norpa-1)

**Characteristic soil properties**

- Weak pedological development in subsoil  
- Sand grading to sandy loam  
- Subsoil pH <5.5

**Land management characteristics**

- Low nutrient retention, deficient in major and minor elements  
- Low pH, susceptible to acidification  
- Wind erosion risk is high in summer and autumn when vegetative cover is limited  
- Plough pan may develop  
- Occasional water seeps occur in mid to upper slope positions
Norpa Soil Series

Representative profile
Profile no. MDN0330
Australian Soil Classification
Acidic Regolithic Orthic Tenosol
Location McAndrew Road, Trayning Shire
AMG 559815mE, 6565551mN, zone 50
Landform Upper to mid-slope on a gently undulating rise, in an upland area
Slope: 2%  Aspect: east
Parent material Lateritic sand from granite
Surface condition Loose surface
Native vegetation Shrubs: *Melaleuca uncinata*

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 15</td>
<td>Dark greyish brown (10YR 4/2) clayey sand; massive structure; earthy fabric; loose soil strength; pH 6.5; clear wavy boundary.</td>
</tr>
<tr>
<td>B21</td>
<td>15 to 100</td>
<td>Brownish yellow (10YR 6/6) fine sandy loam; few faint brown mottles and white bleached sand mottles; massive structure; earthy fabric; very weak soil strength; pH 4.5 (25 cm) pH 4.5 (60 cm) pH 6.0 (100 cm); diffuse boundary.</td>
</tr>
<tr>
<td>B22w</td>
<td>100 to 180+</td>
<td>Brownish yellow (10YR 6/6) fine sandy loam; massive structure; earthy fabric; very weak soil strength; few coarse ferruginous nodules; pH 7.5.</td>
</tr>
</tbody>
</table>

Chemical and physical analysis (<2 mm fraction)

<table>
<thead>
<tr>
<th>Sample Depth (cm)</th>
<th>pH</th>
<th>EC</th>
<th>Al</th>
<th>Org C</th>
<th>Particle size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>0 to 5</td>
<td>5.6</td>
<td>4.7</td>
<td>6</td>
<td>1</td>
<td>1.20</td>
</tr>
<tr>
<td>25 to 30</td>
<td>4.4</td>
<td>4.0</td>
<td>6</td>
<td>19</td>
<td>0.19</td>
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<tr>
<td>60 to 65</td>
<td>4.8</td>
<td>4.5</td>
<td>35</td>
<td>&lt;1</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sampling Depth (cm)</th>
<th>P Total ppm</th>
<th>P PRI ml/g</th>
<th>HCO₃ ppm</th>
<th>K HCO₃ ppm</th>
<th>CaCO₃ %</th>
<th>CEC NH₄Cl me%</th>
<th>Exchangeable cations me%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
<td>Ca</td>
<td>Mg</td>
<td>Mn</td>
<td>K</td>
<td>Na</td>
<td>Al</td>
</tr>
<tr>
<td>0 to 5</td>
<td>150</td>
<td>11</td>
<td>&lt;2</td>
<td>&lt;10</td>
<td>&lt;0.02</td>
<td>&lt;0.2b</td>
<td>0.26b</td>
</tr>
<tr>
<td>25 to 30</td>
<td>28</td>
<td>110</td>
<td>&lt;2</td>
<td>&lt;10</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>0.78b</td>
</tr>
<tr>
<td>60 to 65</td>
<td>22</td>
<td>48</td>
<td>&lt;2</td>
<td>&lt;10</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>0.01b</td>
</tr>
</tbody>
</table>
Northam-1 Soil Series

The Northam-1 Series is commonly called a red dolerite soil. It was first described in the Northam survey [Lanzizke and Fulton 1993]. It has a well structured, red light clay topsoil, on a well structured, red medium clay subsoil, containing soft carbonates. At greater than 80 cm depth it overlies weathered dolerite. This soil is associated with dolerite dykes.

Classification

Australian Soil Classification [Isbell 1995]  
Great Soil Group [Stace et al. 1968]  
Principal Profile Form [Northcote 1979]

Epicalcarentous-Epihypersodic Epipedal Red Vertosol
Red Clay
Ug5.37, Gn3.13

Definition

1: Epicalcarentous-Epihypersodic Epipedal Red Vertosol
2: clay >80 cm on weathered dolerite
3: weathered dolerite
4: A1 B2t Cr
5: -
6: Sandy clay loam grading to medium clay on dolerite rock
7: well drained
8: -

Reference profile

REFKELL6 [McArthur 1991]

Characteristic soil properties

- Clay texture
- Cracks when dry
- Reddish subsoil
- Strongly structured

Land management characteristics

- Good soil water storage
- High natural fertility
- Well drained
- Susceptible to structural degradation
Northam-1 Soil Series

Representative profile
Profile no. MDN0132
Australian Soil Series Epicalcic-Epiforphic Epipedal Red Vertosol
Location Lackman Road
AMG 545804mE, 6589948mN, zone 50
Landform Upper slope
Slope: 1% Aspect: south
Parent material Weathered dolerite
Surface condition Firm surface
Native vegetation Trees: Eucalyptus salmonophloia
Mallees: E. loxophleba

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 5</td>
<td>Reddish brown (5YR 5/3) sandy clay loam; firm soil strength; pH 7.0; clear abrupt boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>5 to 30</td>
<td>Light reddish brown (5YR 6/4) light clay; moderately well developed blocky structure; very firm soil strength; pH 8.0; gradual boundary.</td>
</tr>
<tr>
<td>B2k</td>
<td>30 to 95</td>
<td>Red (2.5YR 4/6) light clay; moderately well developed blocky structure; very firm soil strength; common medium soft calcareous segregations; pH 9.0.</td>
</tr>
<tr>
<td>Cr</td>
<td>95+</td>
<td>Weathered dolerite.</td>
</tr>
</tbody>
</table>
Ulva Soil Series

The Ulva Series is commonly called a gravelly sand. It was first identified in the Merredin survey [Bettenay and Hingston 1961]. Ferruginous gravels increase from a few in the surface to many in the subsoil. It has a greyish brown sandy loam topsoil, grading to a yellowish brown gravelly sandy loam or sandy clay loam subsoil, with abundant ferruginous gravel. Below this is an indurated, mottled, sandy clay loam horizon. The soil is slightly acidic at the surface becoming more acidic with depth. It occurs mainly in upland areas and upper slopes, but occasionally in lower slope positions.

Classification

Australian Soil Classification [Isbell 1995]  
Great Soil Group [Stace et al. 1968]  
Principal Profile Form [Northcote 1979]  

Acidic Ferric Orthic Tenosol
Earthy Sand
Gn2.21, Gn2.22, Gn2.61

Definition

1: Acidic Ferric Orthic Tenosol
2: loam grading to gravelly loam
3: lateritic sand from granite
4: A1/A1c B2wc Cc

5: -
6: gravelly sand loam grading to gravelly sandy clay loam
7: well to moderately well drained
8: -

Similar soil

Norpa: gravelly sand grading to gravelly sandy clay loam

Reference profiles

MDN0325 [Grealish and Wagnon 1995]
P321 CSIRO [Hingston and Bettenay 1961]
REFKELL2 [McArthur 1992]

Characteristic soil properties

• Weak pedological development in the subsoil
• Loam grading to gravelly loam
• Very high gravel content (>20% ferruginous gravels)
• Subsoil pH <5.5

Land management characteristics

• Low water-holding capacity
• Low pH and susceptible to acidification
• High phosphate adsorption
• High gravel content may impede cultivation
• Prone to wind erosion where vegetative cover is poor
Ulva Soil Series

Representative profile

Profile no. MDN0325
Australian Soil Acidic Ferric Orthic Tenosol
Classification
Location McAndrew Road, Trayning Shire
AMG 559324mE, 6564480mN, zone 50
Landform Upper slope on a gently undulating rise, in upland areas
Slope: 3%  Aspect: east
Parent material Lateritic sand and gravel from granite
Surface condition Firm surface
Native vegetation Mallees: Eucalyptus spp. Shrubs: Melaleuca spp.

Morphological description

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 12</td>
<td>Dark grey (10YR 4/1) sandy loam; massive structure; sandy fabric; firm soil strength; pH 5.5; abrupt tongued boundary.</td>
</tr>
<tr>
<td>A2</td>
<td>12 to 22</td>
<td>Very pale (10YR 7/4) sandy loam; massive structure; sandy fabric; firm soil strength; common medium ferruginous concretions; pH 5.0; abrupt wavy boundary.</td>
</tr>
<tr>
<td>B2wc</td>
<td>22 to 60</td>
<td>Very pale brown (10YR 7/3) gravelly sand loam; massive structure; sandy fabric; very firm soil strength; abundant medium ferruginous concretions; pH 5.0; abrupt wavy boundary.</td>
</tr>
<tr>
<td>B2/C</td>
<td>60 to 80</td>
<td>Light yellowish brown (10YR 6/4) gravelly sandy clay loam; massive structure; earthy fabric; strong soil strength; many medium ferruginous soft segregations, pH 5.5.</td>
</tr>
</tbody>
</table>
Landscape processes

It has been suggested that the current model of erosional and depositional surfaces described by Bettenay and Hingston [1964] is not correct. This model depends on gravity and water transport of soil materials, and is commonly used to help understand the complex landscape and soil variation for a large part of the central and eastern wheatbelt. The alternative hypothesis is that soil variation is controlled by aeolian (wind) distribution and redistribution of materials that have blanketed the entire landscape and that water erosion and deposition processes have a minor influence. The evidence for this hypothesis is anecdotal; it has not been formally described, tested and published.

The aim of this survey was not to test models, however, the data partly support the hypothesis of aeolian processes. Evidence comes from the distribution of soils containing calcareous materials occurring throughout the landscape (in valleys e.g. Merredin and Beacon Soil Series, on hill slopes e.g. Booraan Soil Series, and on crests of upland areas e.g. Beacon Soil Series). The source of the carbonate materials could be wind-blown deposits from unknown sources, deposited on the surface and subsequently leached into the soil profile.

Soils developed in aeolian material have been described previously [Bettenay 1962], but their distribution had been limited to parna sheets surrounding salt lakes. The occurrence of calcareous soils high in the landscape (Beacon Series on the crests of the Koorda System which is predominantly a sandplain unit) lends support to the distribution of material by wind.

However, we believe there is a case for both models to operate in the area without being mutually exclusive. The model of erosional and depositional land surfaces [Bettenay and Hingston 1964] appears to work well in the south where it was first described in the adjacent Merredin survey [Bettenay and Hingston 1961]. This could be linked to the uplift of the Kellerberrin batholith which would have encouraged erosion. There are only small upland interfluve areas remaining. To the north and east of the survey area where the landscape is flatter, large upland areas still exist. Evidence of aeolian processes on these stable areas has not been removed by erosion.

The implication to land management is that alkaline loamy fertile soils can be found high in the landscape, not just on the lower slopes and valleys that the traditional concepts would indicate. It may also explain why the sandplain soils which look similar (Norpa, Cunderdin, Holleton) can have markedly different pH values, ranging from highly acidic to neutral. It is possible that the input of calcareous aeolian material has helped to maintain a neutral pH for some soils. This survey was not able to determine a pattern which would assist in predicting acid soil (Holleton) locations.
Soil assessment

Soil assessments are based on current knowledge of soil properties, where the soils are distributed and how they may behave. This information is then used to determine whether the soil is susceptible to a problem (land degradation) or is suitable for a particular use (land use interpretation). This can assist land managers to make management decisions.

In this report the soil series are the basic units used for land use interpretation because their properties remain similar, providing a means for extrapolating knowledge of land behaviour to similar locations. The information provided below is based on the premise that the soil provides anchorage, air, water and nutrients for plants, and that minimising erosion is critical to maintaining a sustainable system.

The method of soil assessment is based on information in the *Soil interpretation manual* [Moore 1996]. Further information was provided by the experience and work of advisers, researchers and farmers, including that from previous publications [Frost and Howell 1990, McArthur 1991, Stoneman 1992] which has been updated where required. The interpretations are based on current knowledge and provide guidance, but should be updated when new information is available.

Soil assessment has been divided into two sections:

- **Soil properties** provide information often required to make land management decisions. Soil properties are classified on objective measurements or inferences (Table 6).
- **Susceptibility to land degradation** provides an assessment on what could happen. It does not necessarily describe the current status, but the susceptibility of the soil to a problem (Table 7).

**Soil properties**

**Unrestricted rooting depth**

This is the depth to a layer that physically restricts plant root growth, i.e. the depth to hardpan, saprolite, bedrock or restrictive clay. This depth is used to determine the volume of soil that is available to a plant from which to extract water and nutrients.

Depth is measured to the physical barrier. It does not take into account all of the factors affecting plant growth, therefore should be considered as a potential maximum which will be reduced by physical factors (e.g. subsoil compaction) or chemical factors (e.g. an acidic or saline layer). Actual plant rooting depth would also depend on the plant’s tolerance to factors such as pH and waterlogging, and the rooting characteristics of the crop or pasture species.

Most soils have a rooting depth of 80 to 150 cm. The deep sandy soils are >150 cm (Cunderdin, Holleton and Norpa Series). Soils in the 30 to 80 cm range are limited by weathered rock (Jura), hardpans (Mollerin and Ulva) and restrictive clay layers (Booraan, Hines Hill, Neening).

**Soil water storage**

Soil water storage measures the ability of the soil to hold and supply water for plants to use. It will determine how long a plant is able to survive before more rain is required. A deep, loamy textured, structured soil will generally have the best soil water storage.
Water storage is primarily determined by soil hydraulic and soil retention properties. They describe how the water moves and is held in soil pore spaces. These spaces depend on the soil structure and texture. Soil water storage is calculated for the volume of soil from which plant roots are able to extract moisture. Maximum rooting depth varies considerably between plants therefore it should be calculated for a specific crop stating the depth. If this is not known, an arbitrary depth interval of 1 m is used, or shallower if there is an impediment to root growth before 1 m.

Coarse sand textures and well structured soils have good hydraulic properties that move water from the surface and through the profile. Good moisture retention is found in soils with sandy loam to clay loam textures (10 to 35% clay). Retention for textures lighter than sandy loam will vary depending on the fine sand and silt component (the higher the better). A well structured soil will retain more moisture than a poorly structured soil with the same texture.

Soil water storage can also be increased if there is a sharp texture contrast between soil layers or a slowly permeable horizon. This will cause water to perch above the layer and increase the natural water retention.

The Jura, Mollerin and Ulva Soil Series have low (<50 mm/m) soil water storage because they are sandy textured and have root impediments within 1 m. The Cunderdin and Holleton Series will be at the lower end of the 50 to 100 mm range as they are coarse sandy soils. The Beacon Soil Series has high (>150 mm/m) storage, is well structured and loamy textured. In this low rainfall environment rainfall frequency may be more important to plant growth than the ability of the soil to store water because it is often insufficient to fill the soil water storage.

**Salinity**

Salinity problems can occur on all soils. Assessment of susceptibility to salinisation is not made here because it is often related to the landscape position and groundwater hydrology. Assessment is limited to the current salt status of the soil. Plant growth is affected by the high soluble salt content reducing the osmotic gradient between the plant roots and soil. This inhibits the uptake of water by plants, although some are more tolerant than others. The extreme problem is a salt crust on the surface with no plant growth.

Salinity can be divided into primary and secondary (dryland) salinity because of different causes. Primary salinity refers to soils that are saline in their natural state; secondary salinity describes soils that have become saline due to a rise in saline groundwater.

Primary salinity is often related to soils with a slow hydraulic conductivity due to poor structure and a loam or heavier (>25% clay) texture. Salts deposited on the soil surface by aeolian activity (wind) will be leached slowly through the soil profile, whereas an equivalent amount of salt on a sandy soil will be quickly leached away.

Secondary salinity can occur in any soil, depending on the watertable and the hydrology of the landscape. Electrical conductivity is used to measure the current salt content.

Soil with high salinity (>200 mS/m) includes the Hines Hill Series (primary salinisation dominant). Moderate salinity (50 to 100 mS/m) occurs in the Merredin, Merredin-1 and Nangeenan Soil Series (primary and secondary). Other soils have low (<50 mS/m) salt levels. However, any soil could be affected by secondary salinisation if on valley floors and/or subject to a general rise in the groundwater to within 2 m of the surface.
pH
Soil pH measures the hydrogen ion concentration determined in a 1:5 soil-water suspension. It is used to describe the soil chemical environment and indicates whether plant growth problems are likely due to nutrient availability or toxicity. Soils that are highly acidic (pH <4.5) or highly alkaline (pH >9.5) are more likely to have problems.

The Holleton Soil Series is acidic throughout (pH <5.5) and the Norpa and Ulva Soil Series become acidic with depth. Beacon, Booraan, Hines Hill, Merredin, Merredin-1, Nangeenan and Neening Soil Series become alkaline (pH >8.5) with depth. All other soils are near neutral (pH 5.5 to 8.5) at depth.

Permeability
Permeability measures the potential of the least permeable layer to transmit water. Assessment is independent of climate and drainage. It indicates how water moves through the soil profile.

The permeability can be measured as saturated hydraulic conductivity or inferred from the soil structure, texture, porosity, cracks and shrink-swell potential. Three soil permeability classes, slow, moderate and rapid, have been defined by Purdie (1993a).

Cunderdin, Holleton and Norpa Soil Series are rapidly permeable because they are deep and sandy. The Ulva, Mollerin, Collgar and Collgar-1 Series have sandy topsoils which have rapid permeability but are assessed as slowly permeable because they have pans in the soil profile. Booraan, Nangeenan and Neening have slow permeability because of clay layers.

Drainage
Drainage describes the rate of water removal and a statement about soil and site drainage likely to occur in most years. Poorly drained soils will have excess water in the root zone, reducing root growth. Other problems caused by poor drainage include run-off causing soil erosion and flooding.

Drainage is assessed on soil and site attributes. Soil attributes include soil structure, texture, porosity, colour and mottling. Site attributes include rainfall, evapotranspiration, gradient and length of slope, and position in the landscape. McDonald et al. 1990 divide soils into six drainage classes from very poorly to rapidly drained.

The sandy soils (Cunderdin, Holleton, Norpa) are well drained, as are the structured soils (Beacon and Northam-1). All others are moderately well to imperfectly drained. Rainfall is low, therefore soils with drainage problems are not expected to severely limit plant growth.

Soil workability
Workability refers to the ease with which the soil can be cultivated or tilled. A soil with a poor workability rating is susceptible to problems that may affect seedbed preparation. Generally, sandy soils are easier to work than clayey soils and well structured surfaces are better than massive (e.g. hardsetting) ones.

Workability is assessed on texture, site drainage, surface condition (structure), stone content, depth to rock and slope angle. These determine the length of time that the soil surface will remain within an appropriate moisture range for cultivation. Too many stones, the presence of rock outcrop, or shallow depth to rock are physical limitations to cultivation. Merredin, Merredin-1, Nangeenan and Neening Soil Series have poor workability ratings based on their clayey topsoil texture and poor structure. There are three classes: good, fair and poor.
Table 6: Summary of soil properties important to land use often required to make land management decisions.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Unrestricted rooting depth (cm)</th>
<th>Soil water storage (mm/m)</th>
<th>Salinity EC mS/m (1:5 water) (0–10 cm)</th>
<th>(50–60 cm)</th>
<th>pH 1:5 water at depths in cm (0–10)</th>
<th>(15–25)</th>
<th>(50–60)</th>
<th>Permeability (3 classes)</th>
<th>Drainage</th>
<th>Soil workability (3 classes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon</td>
<td>80–150</td>
<td>&gt;150</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>7.5–8.5</td>
<td>7.5–8.5</td>
<td>&gt;8.5</td>
<td>Moderate</td>
<td>Well</td>
<td>Good</td>
</tr>
<tr>
<td>Booraan</td>
<td>30–80</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>6.5–7.5</td>
<td>&gt;8.5</td>
<td>&gt;8.5</td>
<td>Slow</td>
<td>Moderately well</td>
<td>Fair</td>
</tr>
<tr>
<td>Collgar</td>
<td>80–150</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>6.5–7.5</td>
<td>6.5–7.5</td>
<td>7.5–8.5</td>
<td>Slow</td>
<td>Moderately well</td>
<td>Fair</td>
</tr>
<tr>
<td>Collgar-1</td>
<td>80–150</td>
<td>100–150</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>6.5–7.5</td>
<td>6.5–7.5</td>
<td>7.5–8.5</td>
<td>Slow</td>
<td>Moderately well</td>
<td>Fair</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>&gt;150</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>Rapid</td>
<td>Well</td>
<td>Good</td>
</tr>
<tr>
<td>Elabbin</td>
<td>&lt;30</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>Moderate</td>
<td>Imperfectly</td>
<td>Fair</td>
</tr>
<tr>
<td>Hines Hill</td>
<td>30–80</td>
<td>100–150</td>
<td>&lt;50</td>
<td>50–100</td>
<td>7.5–8.5</td>
<td>&gt;8.5</td>
<td>&gt;8.5</td>
<td>Slow</td>
<td>Imperfectly</td>
<td>Fair</td>
</tr>
<tr>
<td>Holleton</td>
<td>&gt;150</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>4.5–5.5</td>
<td>4.5–5.5</td>
<td>&lt;4.5</td>
<td>Rapid</td>
<td>Well</td>
<td>Good</td>
</tr>
<tr>
<td>Jura</td>
<td>30–80</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>Moderate</td>
<td>Moderately well</td>
<td>Good</td>
</tr>
<tr>
<td>Korbela</td>
<td>80–150</td>
<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>5.5–6.5</td>
<td>6.5–7.5</td>
<td>6.5–7.5</td>
<td>Slow</td>
<td>Imperfectly</td>
<td>Fair</td>
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<tr>
<td>Merredin</td>
<td>80–150</td>
<td>100–150</td>
<td>&lt;50</td>
<td>50–100</td>
<td>6.5–7.5</td>
<td>7.5–8.5</td>
<td>&gt;8.5</td>
<td>Moderate</td>
<td>Moderately well</td>
<td>Poor</td>
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<td>6.5–7.5</td>
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<td>5.5–6.5</td>
<td>5.5–6.5</td>
<td>7.5–8.5</td>
<td>Slow</td>
<td>Moderately well</td>
<td>Fair</td>
</tr>
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<td>&gt;200</td>
<td>7.5–8.5</td>
<td>&gt;8.5</td>
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<td>Slow</td>
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<td>Poor</td>
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<tr>
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<td>50–100</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>7.5–8.5</td>
<td>7.5–8.5</td>
<td>&gt;8.5</td>
<td>Slow</td>
<td>Imperfectly</td>
<td>Poor</td>
</tr>
<tr>
<td>Norpa</td>
<td>&gt;150</td>
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<td>&lt;50</td>
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<td>Good</td>
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</table>
Susceptibility to land degradation

Water repellence
Water repellence occurs mainly on sandy soils. The result is an uneven wetting pattern which may cause patchy seedling germination. To be repellent a soil requires sufficient hydrophobic organic matter to coat the particles. This can be supplied by legumes and/or native vegetation.

Susceptibility is linked to the surface area of the soil particles which the organic matter has to coat. As clay content increases the particle surface area increases. Clay particles have a surface area up to ten times that of sand and silt sized particles. Susceptible soils tend to have a low clay content (<10%). A soil containing very little clay (<1%) and having a coarse sand texture is highly susceptible.

None of these soils is highly susceptible because they have >3% clay in the surface. The sandy surfaced Cunderdin, Holleton, Norpa and Ulva Soil Series are moderately susceptible because their surface clay contents range between 3 and 10%. Hines Hill and Nangeenan Series are also susceptible because of their highly calcareous ‘fluffy’ surface. These are exceptions to the normal rules.

Structural degradation
Structural decline occurs on loamy or clayey topsoils while sandy topsoils are usually structureless. Structural decline results in increased run-off, reduced water infiltration rates, aeration and traffickability problems, and may reduce seedling germination and moisture availability. It occurs when aggregates are not stable against water and mechanical stress and degrade into primary soil particles. This results in a smaller pore size and less total pore space.

Susceptibility to structural degradation is assessed from texture, electrical conductivity and exchangeable sodium percentage or sodium adsorption ratio. Soils at risk commonly have a sandy loam or heavier (>10% clay) texture. Chemical properties are used to assess whether the soil aggregates will disperse, indicating potentially unfavourable physical characteristics. The Cunderdin, Holleton and Ulva Soil Series are not susceptible because they contain little topsoil clay. All other soils are susceptible.

Subsoil compaction
Subsoil compaction is common on coarse textured (3 to 20% clay) soils. It results in decreased root penetration and root density, reducing access to moisture and nutrients, limiting growth.

Compaction results in smaller soil pore size and pore space through applied stresses, commonly from vehicular traffic and trampling by stock. It is more likely to occur on moist soils. Most soils will compact, but highly susceptible soils are poorly structured, and have a well graded particle size distribution in the clayey sand to sandy loam textures (3 to 20% clay).

Highly susceptible soils include those with a sandy loam topsoil such as Booraan, Korbel, Holleton and Norpa-1 Soil Series.
Subsurface acidification

Soil acidification is a naturally occurring process which is accelerated by agriculture, particularly on sandy soils because of their low pH buffering capacity. Soil acidification changes the chemical environment and affects plant growth in two ways: causing aluminium toxicity which reduces root growth, and causing possible deficiencies of calcium, magnesium, molybdenum, nitrogen and phosphorous required for plant nutrition. Soil acidification is considered at the subsurface (15 to 25 cm).

The susceptibility of a soil to acidification depends on the current pH, pH buffering capacity and acidification rate. The lower the pH buffering capacity the less resistance the soil has to pH change. Buffer capacity can be measured or estimated from the clay and organic matter content. The lower the clay and organic matter the lower the buffer capacity. Acidification rate determines the rate of pH decline, and is related to the land use, productivity and rainfall. The current pH determines how close the soil is to developing a high risk, which is pH (CaCl₂) <4.5.

The Holleton Soil Series is highly susceptible because current pH and buffer capacity are very low. Other highly susceptible soils have sandy textures and a low current pH. These include Cunderdin, Norpa and Ulva.

Wind erosion

Wind erosion can occur on all soils, particularly if the soil surface is disturbed and becomes loose. Wind erosion can result in lower plant growth by sandblasting and plant nutrients carried with the dust into the atmosphere. Offsite pollution can also occur where the dust is deposited. The effects of wind erosion can be minimised by protecting the soil surface with trees, plants, stubble and plant residue.

Susceptibility to wind erosion is related to the level of disturbance required to bring the soil to an erodable condition, not the amount of soil loss. It will depend on the surface condition, texture and presence of stones and gravels. A loose surface will be more susceptible than one that is firm or hardsetting. As texture becomes heavier (increase in clay) the soil generally becomes less susceptible to erosion. Gravels and stones reduce the amount of surface exposed to the wind, and also create roughness which reduces the erosive velocity.

Highly susceptible soils are those with a loose, sandy surface and include the Cunderdin, Holleton, Norpa and Ulva Soil Series.

Water erosion

Water erosion can occur on all soils. The effect is to remove soil material and nutrients from a site, reducing sustainable plant growth at that site. Offsite pollution can occur where the sediments are deposited.

For water erosion to occur, run-off and soil detachment are required. Run-off can occur when the topographic factors (slope angle, length, form, run-on) encourage surface water to move. Excess water on the surface occurs when rainfall intensity exceeds the surface infiltration rate and/or when the surface soil water storage is exceeded and ponding occurs. Soil detachment depends on the soil texture, surface condition and the stability of soil aggregates. Medium textured (10 to 35% clay) soils, loose surfaces and unstable aggregates are highly susceptible to water erosion. Moderately susceptible soils are the Booraan, Elabbin and Northam-I Soil Series. This is mainly due to their landscape position (3 to 8% slopes) and surface condition.
Table 7. Susceptibility of soil series to land degradation, rated Low (L), Moderate (M) or High (H).

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Water repellence</th>
<th>Structural degradation</th>
<th>Subsoil Compaction</th>
<th>Subsurface Acidification</th>
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<tr>
<td>Northam-1</td>
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<tr>
<td>Ulva</td>
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<td>M</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>
Glossary

Aeolian: Soil material transported by wind.

Alluvium: An accumulation of sediments deposited by or in transit in flowing water.

Batholith: A shield-shaped mass of igneous rock intruded into older formations.

Clay: Particles <0.002 mm in diameter. When used as a soil texture group, the soil contains >35% clay.

Colluvium: Unconsolidated material moved largely by gravity (i.e. mass movement).

Craton: A relatively immobile part of the earth, generally of large size. The Yilgarn Craton is one of the best known cratons in Western Australia.

Gilgai: Surface microlrelief associated with soils containing shrink-swell clays. Gilgai consist of small, irregularly distributed mounds and depressions, separated by a more or less continuous plain. The vertical interval is usually <0.3 m and the horizontal interval about 3 to 10 m.

Gley: The grey of greenish-grey colouration found in soils. It is often produced under conditions of poor drainage, which give rise to microbial oxygen depletion and chemical reduction of iron and other elements.

Hardpan: A hardened, compacted and/or cemented horizon in the soil profile.

Hardsetting: Hard, compact, apparently apedal condition, that forms on drying but softens on wetting. When dry, the material is hard below any surface crust and is not disturbed or indented by pressure of forefinger.

Horizon: Layer within a soil profile which has morphological properties different from those layers above or below.

Indurated: Adjective used to describe a layer of material hardened by cementation or pressure.

Kaolin: A rock composed essentially of clay minerals of the kaolinite group; usually pale coloured and frequently found below breakaways.

Laterite: A residual deposit in which an indurated iron-rich layer usually overlays a mottled clay or a pallid clay.

Loam: A medium textured soil group composed of approximately 10 to 25% clay, 25 to 50% silt and <50% sand.

Loose: Incoherent mass of individual particles or aggregates. Surface is easily disturbed by pressure of forefinger.

Mafic: Composed of the magnesian, rock-forming silicates.

Massive: Adjective used to describe soil structure when it is composed of no observable peds and two-thirds or more will remain united at the given moisture state unless force is applied. It will separate into particles under force.

Medium sand: Soil comprising particles of 0.2 to 0.6 mm diameter which can be seen easily and have a similar feel to white sugar.

Morphological properties: Properties assessed by feel or visual description in the soil.
Mottles: Blobs or blotches of soil colour that differ from the dominant soil matrix colour in the same horizon.

Nodule: A small concretionary deposit, usually sesquioxides and/or manganese and/or carbonates; usually hard.

Parna: Clay-sized material that forms aggregates which are wind-blown and deposited as sheets in the landscape. The aggregates are often highly calcareous and dominated by the clay fraction.

Ped: An individual natural soil aggregate.

pH: Measure of the acidity or alkalinity of the soil. A pH of 7.0 measured in water indicates neutrality, higher values indicate alkalinity and lower values acidity. Soils with pH >10.0 are considered highly alkaline and pH <4.5 is normally too acid for plant growth.

PPF: Abbreviation for Principal Profile Form, a term given to the endpoint of the Northcote factual key soil classification.

Redox: Describes the reduction and oxidation process. Often related to mottles formed by this process.

Rooting condition: Refers to the amount of soil volume available for plant root development and the impedance to root development. Soil volume can be reduced by rock and gravel content or by dense hardpans, clay layers and toxic chemical concentrations. Different plants vary in their ability to explore the soil profile.

Sand: Soil particles between 0.02 and 2 mm in diameter. When the term is used to describe a texture group the soil usually contains less than 5% clay. Such soils cannot be moulded when moist and coherence is very slight.

Saprolite: Decomposed rock characterised by the preservation of structures that were present in the unweathered rock.

Silt: Soil particles between 0.02 and 0.002 mm in diameter.

Sodic: Description for soil containing >6% exchangeable sodium. Sodic soils adversely affect soil stability, plant growth and/or land use.

Subsoil: A soil layer below the surface characterised by (a) concentration of clay and/or iron and/or aluminium, (b) having structure and/or consistence unlike the layers above and below; (c) having stronger colours than those horizons above and below. It is designated as a B horizon.

Subsurface: A soil layer directly below the surface horizon and above the subsoil. This layer does not always occur, but when it does is usually found from 10 to 40 cm deep. It is often described as an A2 horizon.

Topsoil: Surface soil layer containing organic material which makes it a darker colour and more fertile. Designated as an A horizon.

Water repellent: Soil which resists wetting when dry. This occurs because of the presence of waxes from plant residues that coat the sand grains, causing water to run off.

Watertable: Depth below the soil surface where there is a free water surface.

Workability: Descriptive term for ease of using agricultural implements in a soil.
Acknowledgements

The authors wish to acknowledge all who assisted with this project. In particular, we thank:

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- Jim Dixon and Noel Schoknecht for project coordination;
- Department of Mines and the Chemistry Centre for physical and chemical analyses of soil samples;
- Department of Land Administration for aerial photographs and satellite images;
- Document Support Centre and Graphic Design staff for valuable assistance;
- Noel Schoknecht for photographs.

The water pipeline is a great asset in the Bencubbin area where natural fresh water is scarce.
References


Lantzke, N. and Fulton, I. (1993). *Land resources of the Northam Region* (Land Resources Series No. 11). Department of Agriculture Western Australia.


Replanting trees in the landscape helps offset rising watertables which can lead to salinity problems.
Appendix

Soil series heading descriptions and details of laboratory analysis used in soil series definitions

Classification
Australian Soil Classification [Isbell 1995]
Great Soil Group [Stace et al. 1968]
Principal Profile Form [Northcote 1979]

Definition
The definition specifies criteria used to define the soil series. 

Essential criteria (these must be part of the series definition)
1. Australian Soil Classification [Isbell 1995] to subgroup
2. texture group cross-referenced to depth and contrast
   sand, loam, clay, gravel, substrate
   <30 cm, 30 to 80 cm, >80 cm
   grading to..., over..., on...
3. soil parent material
4. essential diagnostic or genetic horizons

Optional criteria (may be part of the series definition)
5. additional depth intervals <15 cm, >150 cm
6. fine texture differences
7. drainage class [McDonald et al. 1990]
8. permeability profile (based on hydraulic conductivity data)

Similar soils
Identifies similar soils and the features that distinguish them.

Variants recognised
A variant is a soil that differs slightly in only one of the criteria used to define the series and the difference is insufficient to change the land use interpretation of the soil. This is identified by the series name with a numerical suffix e.g. Merredin-1.

Reference profiles
These are profiles with good data that illustrate most of the characteristic features of the series. They are identified by the survey code and site number which also identifies the site in the soil profiles database.

Characteristic soil properties
Describes the main soil features.

Land management characteristics
Describes significant features of the soil with respect to land management. Based on qualitative assessment.

Representative profile
A soil profile description representative of the series in the survey area. May include analytical data.
Abbreviations and units of laboratory analysis

Analysis by Chemistry Centre Western Australia
(For description of analytical methods see Overheu et al. 1993 p. 93, or Moore 1996)

<table>
<thead>
<tr>
<th>%</th>
<th>per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al (CaCl₂)</td>
<td>Aluminium Al, extracted in 0.01M CaCl₂</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>Calcium carbonate, soluble in dilute acid</td>
</tr>
<tr>
<td>CEC</td>
<td>Cation Exchange Capacity (methods a, b or c)</td>
</tr>
<tr>
<td>a</td>
<td>extracted in 1M NH₄Cl pH 7.0</td>
</tr>
<tr>
<td>b</td>
<td>extracted in 0.1M CaCl₂</td>
</tr>
<tr>
<td>c</td>
<td>extracted in 1M NH₄Cl pH 8.5</td>
</tr>
</tbody>
</table>

Exchangeable cations
- Al (exch) | Aluminium Al |
- Ca (exch) | Calcium Ca |
- K (exch) | Potassium K |
- Mg (exch) | Magnesium Mg |
- Mn (exch) | Manganese Mn |
- Na (exch) | Sodium Na |

EC (1:5) | Electrical conductivity (1:5) at 25°C |
K (HCO₃) | Potassium K, extracted in 0.5M NaHCO₃ (1:100) |
me% | milliequivalents per cent (milliequivalents per 100 g of soil) |
ml/g | millilitres per gram |
mS/m | milliSiemens per metre (100 mS/m = 1 dS/m) |
OrgC (W/B) | Organic carbon C, Walkley and Black method |
P (HCO₃) | Phosphorus P, extracted in 0.5M NaHCO₃ (1:100) |
P (PRI) | Phosphorus Retention Index |
P (total) | Phosphorus P, total |

Particle size analysis | Organic carbon and calcium carbonate not removed by pretreatments |
pH (CaCl₂) | pH (1:5) in 0.01M CaCl₂ |
pH (H₂O) | pH (1:5) in water |
ppm | parts per million |
Other Land Resource Series Reports

No. 1. Land capability assessment methodology for rural-residential development and associated agricultural land uses (1989)
No. 2. Land capability study of the shires of Mandurah and Murray (1989)
No. 3. Darling Range rural land capability study (1990)
No. 4. Geraldton rural-residential land capability study (1990)
No. 5. Busselton, Margaret River, Augusta land capability study (1990)
No. 6. Land capability study for horticulture in the Swan Valley (1991)
No. 7. Soils of the Mount Beaumont area (1996)
No. 9. Land resources study of the Carnarvon Land Conservation District and part of Boolathana Station, Western Australia (1992)
No. 10. Soils and landforms of the Manjimup area (1992)
No. 11. Land resources of the Northam region (1993)

Maps accompanying these reports can also be purchased separately.

Other land resource maps
Land Resources of the Peel-Harvey North Region
Land Resources of the Peel-Harvey South Region

Maps and reports are available from
Agriculture Western Australia
Baron-Hay Court
South Perth 6151

Some copies are also held in local offices. Credit card sales can be arranged by telephoning (09) 368 3710.
Natural Resources Assessment Group, Agriculture Western Australia

SOIL/SOIL LANDSCAPE MAPPING
IN SOUTH WESTERN AUSTRALIA

Status at November 1995

- Bencubbin Land Resources Series No. 12
- Other Land Resources Series reports
- Land Resources Surveys in progress
- Land Resources Surveys completed by other organisations
- Area not yet surveyed

- Boundary of agricultural area

Land Resources Report series
(See full listing inside)

2 Land capability study of the shires of Mandurah and Murray
3 Darling Range rural land capability study
4 Geraldton rural-residential land capability study
5 Busselton Margaret River Augusta land capability study
6 Land capability study for horticulture in the Swan Valley
7 Soils of the Mt. Beacon area, WA, Stages I and II
8 Esperance land resource survey
10 Soils and landforms of the Manjimup area, Western Australia
11 Land resources of the Northam region
12 Land resources of the Bencubbin area