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# Land Resources Bulletin

## Agricultural Land Resource Assessment of Coalstoun Lakes, Queensland


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Queensland Government

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# Contents

Page

## List of Tables



## List of Figures



## Accompanying map

## Summary

Coalstoun Lakes is a local area of about 8000 ha within the Central Burnett region of Queensland and is currently dominated by broadacre cropping. The need for detailed land resource information within the Coalstoun Lakes area has increased in priority due to the proposal to pump irrigation water from a proposed dam on either the Burnett River or Barambah Creek.

This study will support strategic planning and sustainable use for the Coalstoun Lakes area by identifying areas prone to or affected by land degradation, land suitable for existing and potential industries, good quality agricultural land and by developing land management guidelines. The existing land system mapping is too broad to supply the information to address these issues. Land Resource Officers from Resource Management in South East Region have completed a medium intensity (1:50 000) soil survey of 7655 ha and assessed the suitability of these soils for a range of irrigated agricultural and horticultural crops.

A total of fifteen different soils have been identified and their distribution mapped. The dominant soils are black and grey cracking clays (Vertosols) and non-cracking red clay soils (Ferrosols), red and brown structured gradational soils (Dermosols) and sodic texture contrast soils (Sodosols).

Over 50% of the area mapped (3995 ha) are Ferrosols developed on basalt. These soils are suited to a wide range of agricultural and horticultural crops. In the remaining area, 25% of the area are soils developed on alluvium and colluvium (1996 ha), soils formed on Biggenden Beds (775 ha) or on a range of geologies with slopes greater than 8%.

A total of 6290 ha suitable for sugarcane, 5793 ha for asparagus, cruciferae and vegetables, 5713 ha for beans, 5793 ha for cucurbits, 4190 ha for lucerne, 5580 ha suitable for navybean and potato, 4596 ha for sorghum, 4418 ha for soybean, 4596 ha for sweet corn, 5660 ha for sweet potato, 6281 ha for avocado, macadamia, citrus, lychee and mango, 4325 ha for grapes, 4288 ha for stonefruit, 4781 ha for peanuts, 4595 ha for maize and 6591 ha for pasture. Furrow irrigation of sugarcane is suitable on 1284 ha of land.

The possibility of future salinisation in some areas will affect future irrigation management within the Coalstoun Lakes area. Widespread inefficient irrigation development of the highly permeable Red Ferrosols may cause seepage downslope with localised or general rises in watertables where these permeable soils contact with less permeable Dermosols and Vertosols soils such as *Fletcher* and *Hind*. These hazard areas have been identified. There is evidence of minor seepage occurring in these areas even under rainfed conditions. Future irrigation systems will need to be designed so as the amount of water being applied does not exceed crop uptake needs, and monitoring be undertaken to ensure irrigation management is sustainable.

# 1. Introduction

Coalstoun Lakes is located approximately 25 km east of Gayndah in the Central Burnett region of Queensland. Broadacre cropping systems dominate the agricultural production, with a small number of dairies operating within the region. Peanuts, maize and sorghum are predominantly grown in the summer months, while wheat is the main winter crop produced in the area.

Local farmers have a perception that there is a large potential for irrigation development within the Coalstoun Lakes area. The existing issues associated with current land uses, such as physical and chemical decline of the Ferrosols, and potential degradation and environmental issues which may be associated with irrigation development, necessitates the need for a detailed land resource information base to ensure sustainable agricultural development.

The land resource information from this study will be used to support catchment management planning, strategic planning and for the sustainable use and management of SEQ lands by:

- identifying areas prone to or affected by land degradation (salinity/erosion/soil structure/acidification)
- identifying land suitable for existing and potential agricultural industries
- identifying good quality agricultural land for designation in planning schemes
- developing sustainable land management guidelines in cooperation with landholders, Landcare, ICM groups, Government Departments and others.

The study area may be seen in Figure 1 and a typical landscape photographs in Figures 2 and 3.

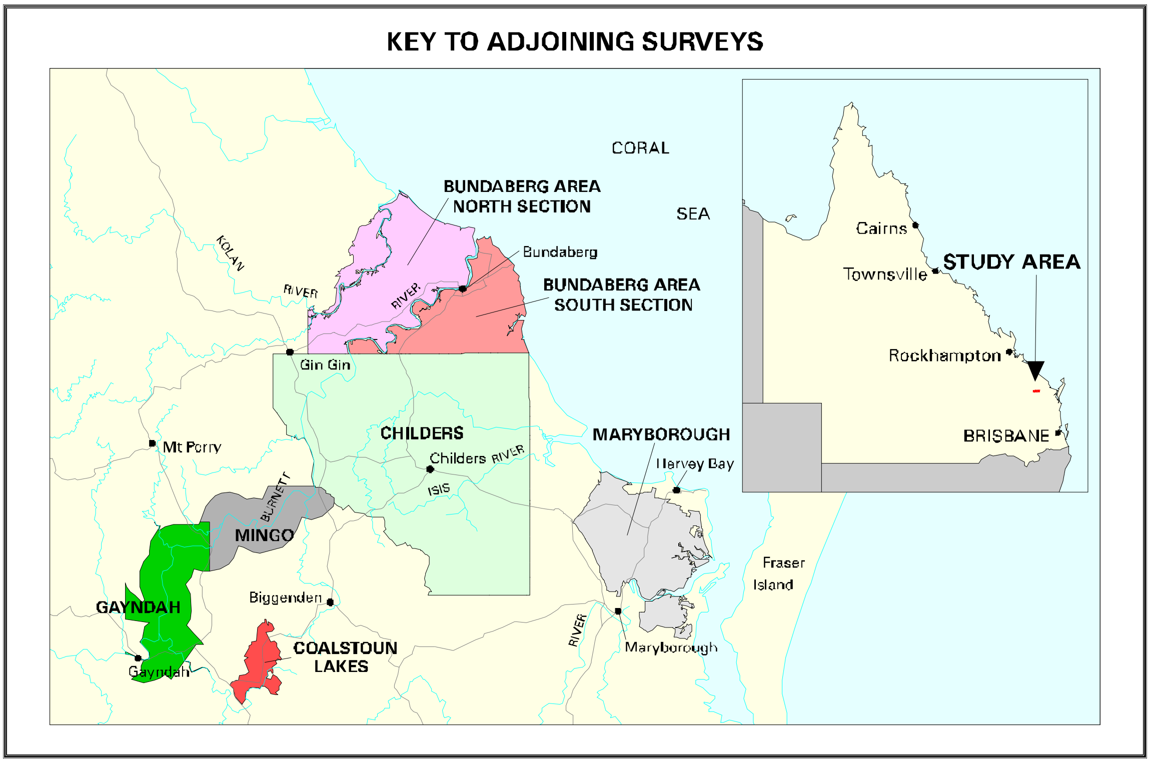


**Figure 1.** Locality map

**Figure 2**. Typical landscape photograph, wheat crop in foreground and one of the craters in the background

**Figure 3**. Photograph of a typical rockpile on the edge of cultivated lands

# 2. Study Area

## 2.1 Climate

The climate for the inland Burnett District is subtropical with long, hot summers and mild winters. The mean daily maximum temperature is 32.6°C in December. Temperatures frequently exceed 35°C during the summer months of December and January. July has the lower mean daily temperature of 5.9°C. Frost does occur in the study area, but only in low lying areas.

The average annual rainfall for the area is 772.9 mm. Approximately 70% of the total rainfall occurs in the summer months of October to March. Below average rainfall is a regular feature in the district. On average, the study area is drought declared approximately once every five years (Mahar 1993). Mean daily temperature and rainfall can be seen in Table 1.

**Table 1.** Mean daily temperature and rainfall recorded at Gayndah Post Office

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Daily Max. Temp. (deg. C) | | | | | | | | | | | | |
| 32.5 | 31.8 | 30.7 | 28.5 | 25.1 | 22.3 | 21.8 | 23.6 | 26.7 | 29.4 | 31.5 | 32.6 | 28.0 |
| Mean Daily Min. Temp. (deg. C) | | | | | | | | | | | | |
| 19.9 | 19.8 | 18.0 | 14.3 | 10.3 | 7.4 | 5.9 | 6.7 | 10.0 | 14.0 | 17.0 | 19.0 | 13.5 |
| Mean rainfall (mm) | | | | | | | | | | | | |
| 117.2 | 106.9 | 76.6 | 38.5 | 41.3 | 39.8 | 39.4 | 29.3 | 35.5 | 64.6 | 77.1 | 106.8 | 772.9 |

Bureau of Meteorology

## 2.2 Geology

The Central Burnett region is a complex mixture of metamorphic, igneous and sedimentary rocks. Basalts are prominent in the Coalstoun Lakes area and are surrounded by sedimentary rocks to the west, and acid volcanics to the east. Small areas of alluvial deposits may be found along creeks.

The Barambah Basalt Formation was extruded from the volcanic vents along the Perry Fault line in the Coalstoun Lakes area. The fluid lavas flowed south down the valley of Sandy Creek, into Barambah Creek, and then North into the Burnett River for a distance of approximately 150 km and is up to 20 metres thick (Ellis 1968).

A thin veneer of recent alluvium covers the Barambah Basalt, where the floodplains of Sandy and Barambah Creeks coincide with the lava plain.

The Biggenden Beds, of lower Permian age, are comprised of a folded sequence of sandy silty sediments, volcanics, chert and limestone to the west and north of Sandy Creek. The beds are weathered, and are grey, green, brown or red.

The Aranbanga Volcanic Group includes andesite to rhyolitic flows, pyroclastic rocks, minor sediments and basalt. This geological unit corresponds to the steep hills and mountains to the east of Coalstoun Lakes.

## 2.3 Landform

The landscapes of the Coalstoun Lakes area range from an undulating lava plains surrounded by steep hills and small areas of alluvial plains.

The main features of the study area are the undulating plains of the Barambah Basalt. This area is characterised by low relative elevation and low slopes. The largest elevation differences on the lava plain are caused by the varying ages of the component lava flows. Rocks and high slopes are a common occurrence on the boundaries of these flows. The lava flows originate from four volcanic vents located at the northern end of the Coalstoun Lakes valley. These vents have steep rocky sides and a central crater.

A drainage line, which dissects the lava plain, flows into Sandy Creek which follows the eastern edge of the basalt south, finally entering Barambah Creek south of Ban Ban Springs. The drainage line has a narrow alluvial plain, comprising alluvium from the basalt and surrounding geologies. Sandy Creek, west of Ban Ban Springs, has areas of significant alluvial plains and very narrow levees.

The hills surrounding Coalstoun Lakes are formed on Biggenden Beds and Aranbanga Volcanics. The Aranbanga Volcanics and Biggenden Beds for a chain of steep hills, on the eastern and western side of the study area respectively. Gravelly colluvial pediments and small alluvial fans occur at their base.

# 3. Methodology

## 3.1 Soil survey

A free survey technique was used which utilised aerial photo interpretation to assist in the location of soil boundaries. Colour aerial photographs at a scale of 1:25 000 were used in the field to locate soil boundaries and mapping sites.

All field work was conducted by vehicle traverse. A total of 160 mapping sites were described and stored on computer in a site description database. This site intensity approximates to one site per 48 hectares, appropriate for a 1:50 000 scale intensity.

Australian Map Grid (AMG) coordinates were recorded for each mapping site on the site description file. All map unit boundaries have been entered onto a GIS. Each map unit within the study area was numbered with a unique identifier and referred to as a Unique Map Area (UMA). Each UMA identifies the dominant soils, landform, geology, vegetation, existing land uses, any degradation and land attributes. The attributes include incidence of frost, soil plant available water capacity, degree of rockiness, permeability and drainage, soil depth, microrelief, landscape complexity, erosion, slope and surface condition.

A description of the soil profile and information on vegetation, soil surface characteristics, microrelief (gilgai) and slope were recorded at each mapping site using standard terminology and codes of McDonald *et al.* (1990). See Appendix I.

Samples of 6 representative soil profiles and subsoils of other selected profiles were collected for laboratory analysis. The results of these are attached in Appendix II.

# 4. Soils

A total of 15 soils were identified, including cracking and non-cracking clay soils, texture contrast soils and gradational soils. A brief description and classification of each soil type is given in Table 2.

**Table 2.** Distinguishing attributes of soil types

| Soil type | Distinguishing features | Australian Classification† | Geology |
|---|---|---|---|
| Bellert | Greyish brown or dark brown, massive to weakly sub blocky, clay loam surface (up to 0.63 m thick); over dull reddish brown or reddish brown, strong sub-angular blocky subsoil; light medium clay; slightly acid to neutral; coarse fragments very abundant. | Red Sodosol | Biggenden Beds |
| Bellert gradational variant | As above with a gradational texture change between the surface and subsoil. | Red Dermosol | Biggenden Beds |
| Blair | Dull reddish brown, sub-angular blocky, light medium to medium clay surface; over dull reddish brown or brown, strong lenticular, medium clay to medium heavy clay subsoil; few manganiferous nodules; neutral to alkaline. | Red Dermosol<br>Brown Vertosol | Biggenden Beds |
| Blair, non-vertic variant | Dark reddish brown, strong polyhedral, light medium clay surface; over dark reddish brown, polyhedral clay subsoil; slightly acid to alkaline; few small pebbles; rock at > 0.25 m. | Red Dermosol | Biggenden Beds |
| Crater | Brownish black, polyhedral, medium clay surface; over brownish black, lenticular, medium clay to medium heavy clay subsoil; neutral to alkaline. | Black Ferrosol | Barambah Basalt |
| Dove | Brownish black, granular, medium clay to medium heavy clay surface; over brownish grey, lenticular, medium heavy clay to heavy clay subsoil; few carbonate nodules; alkaline. | Grey Vertosol | Colluvium from Biggenden Beds |
| Fletcher | Dark brown or greyish black, granular, light clay to light medium clay surface; over dull yellowish brown or brown or black, sub-angular blocky or lenticular, light clay to light medium clay subsoil; neutral to alkaline. | Black Dermosol<br>Brown Dermosol | Barambah Basalt |
| Fletcher, shallow variant | Brownish black, polyhedral, light medium clay surface; over brownish black, polyhedral, light medium clay subsoil; few manganiferious nodules; neutral; basalt rock at >0.25 m. | Black Dermosol | Barambah Basalt |

† Isbell (1996)

**Table 2 (continued)**

| Soil type | Distinguishing features | Australian Classification† | Geology |
|---|---|---|---|
| Fowler | Thin to medium thick (0.1 – 0.3 m), brownish black, massive to weakly granular, fine sandy clay loam to clay loam surface; bleached sub-surface; over brown or greyish yellow brown, sub-angular blocky to lenticular, light medium to medium clay subsoil; neutral to alkaline. | Brown Sodosol<br>Grey Sodosol | Quaternary alluvia |
| Hind | Brownish black, granular, medium heavy clay to heavy clay surface; over brownish black to dark greyish yellow, vertic medium clay to medium heavy clay subsoil; carbonate nodules; alkaline. | Black Vertosol<br>Grey Vertosol | Barambah Basalt |
| Hunter | Greyish brown or brownish black, granular to sub-angular blocky, light clay to light medium clay surface; over brownish black, grey or yellow brown, lenticular, light medium to medium clay subsoil; carbonate nodules; alkaline. | Black Vertosol<br>Grey Vertosol | Quaternary alluvia |
| Sandy | Very thick (>0.6 m), brownish black or grey, massive loamy sand to sandy clay loam surface; over dark brown or yellowish orange, massive; sandy loam to sandy clay loam sub-surface; over dull reddish brown or brown, sub-angular blocky sandy medium clay subsoil; neutral. | Brown Sodosol | Quaternary alluvia |
| White | Dark reddish brown, granular, light medium clay to medium clay surface; over reddish brown or dark reddish brown, polyhedral, light medium clay to medium clay subsoil; acid to neutral. | Red Ferrosol | Barambah Basalt |
| Witton | Dark reddish brown, granular, light clay to light medium clay surface; over dark reddish brown, polyhedral, light clay to light medium clay subsoil; acid to neutral. | Red Ferrosol | Barambah Basalt |
| Witton, vertic variant | As above, with strong lenticular structured subsoil. | Red Ferrosol | Barambah Basalt |

† Isbell (1996)

## 4.1 Soil landscapes

Soils derived from basalt dominate the Sandy Creek valley in the Coalstoun Lakes area. Figures 4, 5 and 6 illustrates the general relationship between the basaltic soils and landscape in the Coalstoun Lakes area.

The *Crater* soil type occurs on the hillslopes of the four volcanoes in the area. *Witton* occurs on the younger lava flows and characteristically has softwood scrub vegetation. *White* has predominantly Eucalypt forest vegetation and occurs on the older lava flows. *Fletcher* and *Hind* are found around the edges of the basalt flows. *Fletcher* is less weathered than *Witton* and *White,* and has poorer drainage. *Hind* is the soil lowest in the basalt landscape and has undergone less weathering than the other basaltic soils.

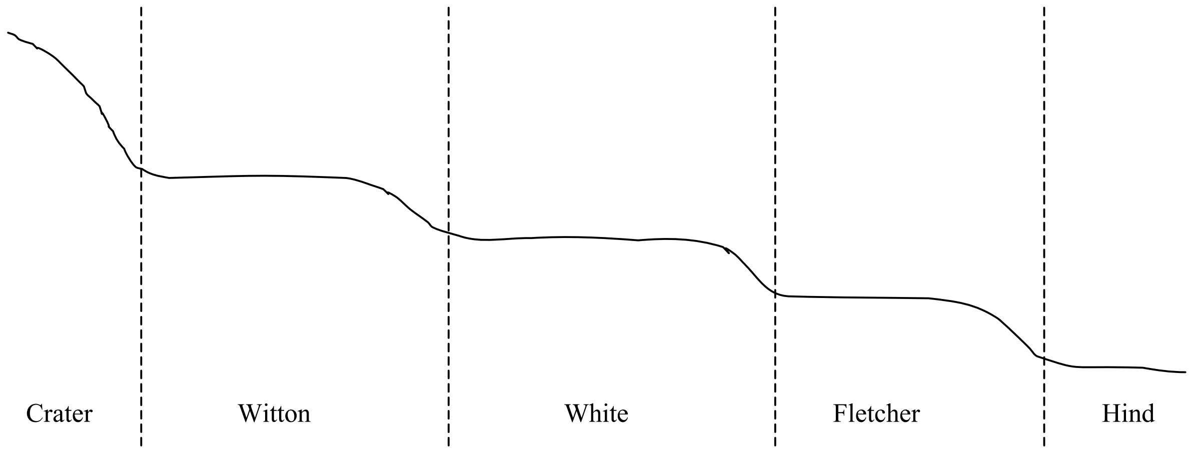


**Figure 4.** Soil landscape units of the basalt landscape

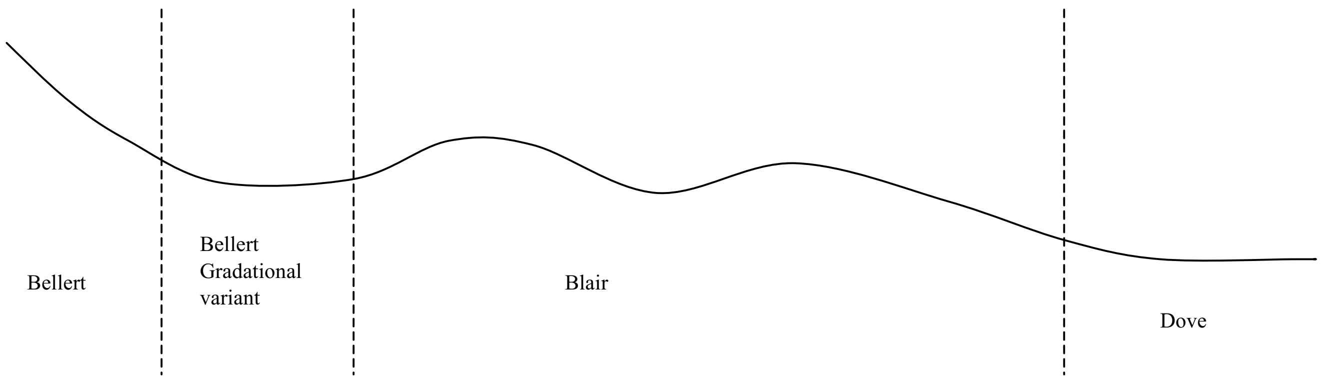


**Figure 5.** Soil landscape units of the Biggenden Beds landscape

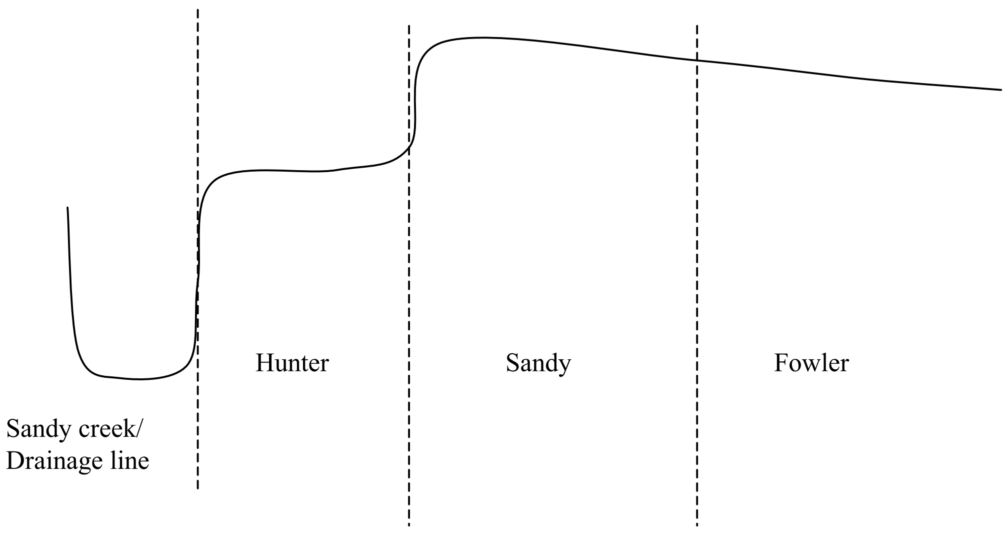


**Figure 6.** Soil landscape units of the alluvial landscape

The Biggenden Beds landscape encases the Barambah Basalt flows of the Coalstoun Lakes area. The *Bellert* soil is found on the hillslopes and has an abundance of gravel throughout the soil profile. The *Bellert gradational variant* occurs in association with *Bellert*, often at the footslopes and colluvial fans. *Blair* occurs on volcanic rises that outcrop and surround the Barambah Basalt. The *Dove* soil type is formed on colluvial deposits from the surrounding material.

The alluvial system consists of three soil types. All of which do not always occur concurrently. *Hunter* is a dark or grey cracking clay soil, which occurs within the drainage lines. *Sandy* is a thick sandy surfaced texture contrast soil, which occurs on levees adjacent to Sandy creek. *Fowler* is a texture contrast soil, which occurs on the back plains of the alluvial landscape.

## 4.2 Chemical and physical attributes

### pH

Soil pH provides a measure of the degree of acidity or alkalinity of the soil solution and has a major influence on plant nutrient availability. High subsoil pH may also indicate high levels of exchangeable sodium (McCarroll 1998), if associated with moderate to high levels of calcium.

All of the well-drained soils have field pH values which are neutral to slightly alkaline at depth (*Witton*, *Witton* Vertic variant, *White*, *Sandy*). All other soils have a strongly alkaline field pH at depth (Figures 7, 8 and 9). The less weathered basaltic soils (*Crater, Hind, Fletcher*) are darker in colour and are more alkaline than the highly weathered soils (*White and Witton*).

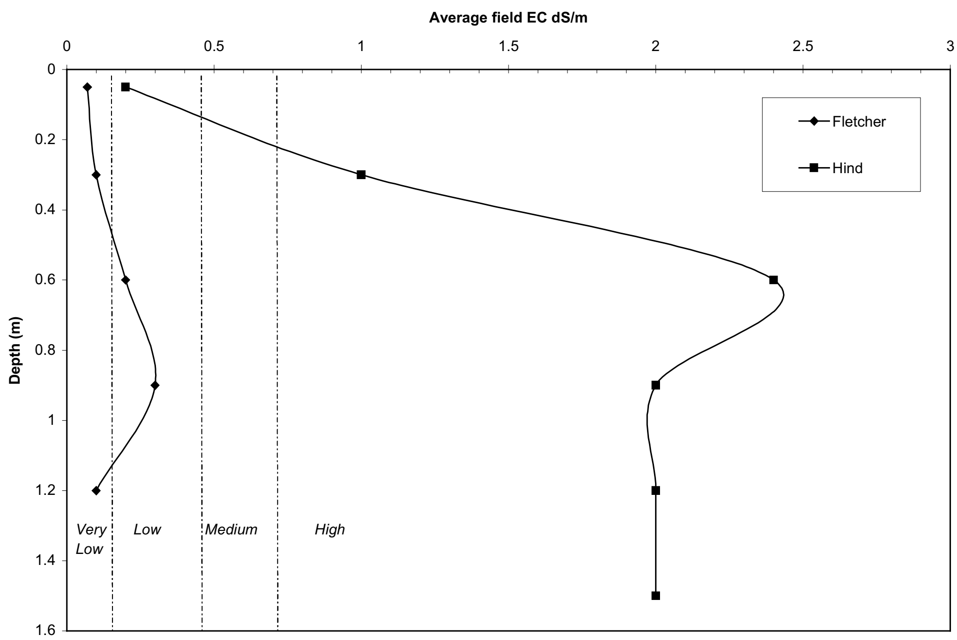


**Figure 7.** Average field pH values of basaltic soils *Crater*, *Witton*, *White*, *Fletcher* and *Hind*

Well-drained soils on the alluvial system (*Sandy*) have their profiles flushed regularly maintaining a neutral pH. The other soils in the alluvial system have higher clay content and are not as freely drained. These soils show an increase in pH at depth. Calcium carbonate deposits produce alkaline pH, and accumulate at the depth to which regular wetting occurs. This also may be used as an indicator of the soil rooting depth.

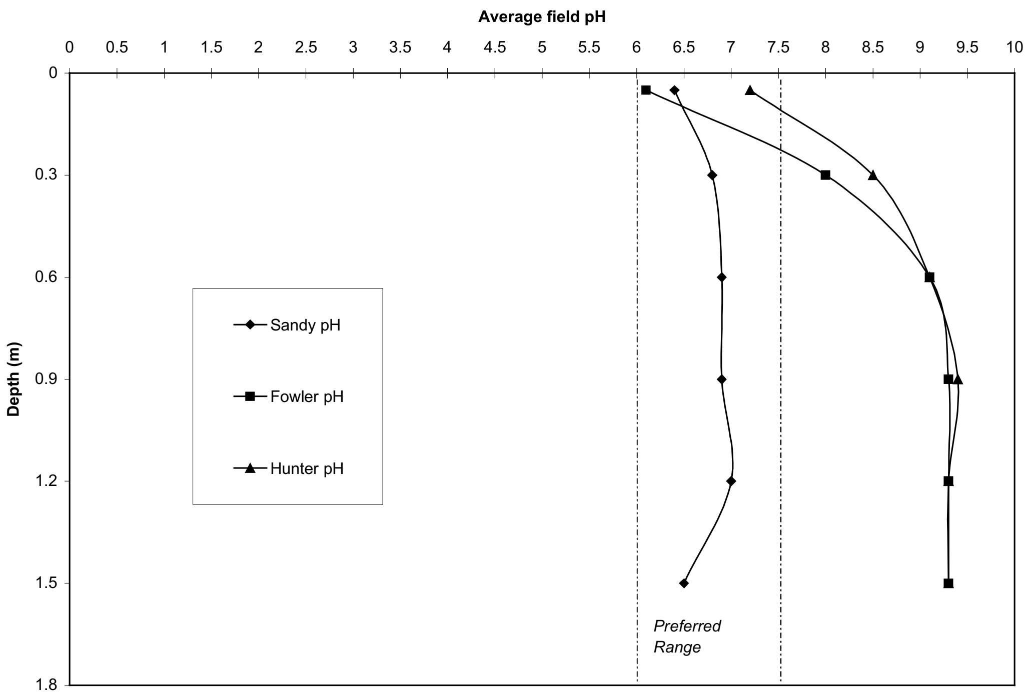


**Figure 8.** Average field pH values of soil types *Sandy*, *Fowler* and *Hunter*

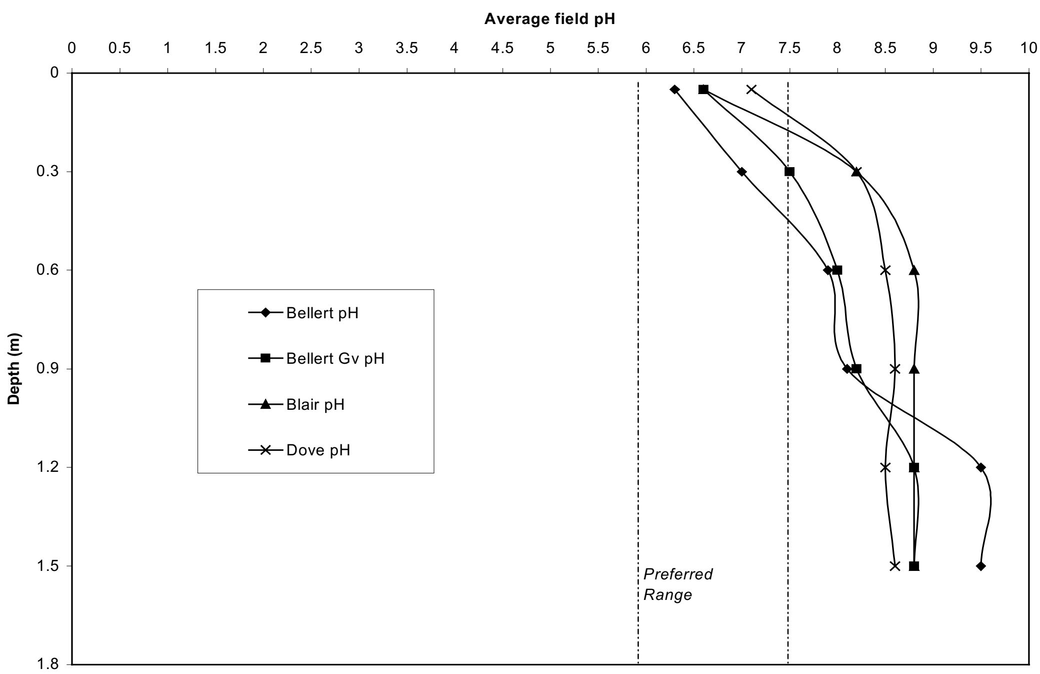


**Figure 9.** Average field pH values of *Bellert*, *Bellert Gradational variant*, *Blair* and *Dove*

## Salinity

The level of soluble salts is an important attribute as excessive quantities affect crop growth by reducing water availability through osmotic pressure effects and by toxicity effects on plant metabolism (Donnollan *et al.* 1990). Salinity ratings are derived from field measurements of electrical conductivity (EC) in a soil:water 1:5 suspension. EC alone measures all salts in the soil, including contributions from less soluble sources of salts like gypsum.

The cracking clay soils, *Dove*, *Hind* and *Hunter*, have a high to extreme conductivity level by 0.6 m or 0.9 m. The extremely high EC readings in the *Hind* soil type reflect the incidence of gypsum within the profile. The Sodosols and Dermosols formed on alluvium and Biggenden Beds (*Bellert, Blair, Dove, Fowler*) also have high salinity readings by 0.6 or 0.9 m (Figures 10, 11 and 12). All other soils (*Crater, Fletcher, White, Witton* and *Sandy*) are low in salts.

Highly weathered soils are freely draining therefore they leach salts readily through the profile. Other soils usually have an accumulation of salts at a depth where regular wetting occurs or an impeding layer occurs.

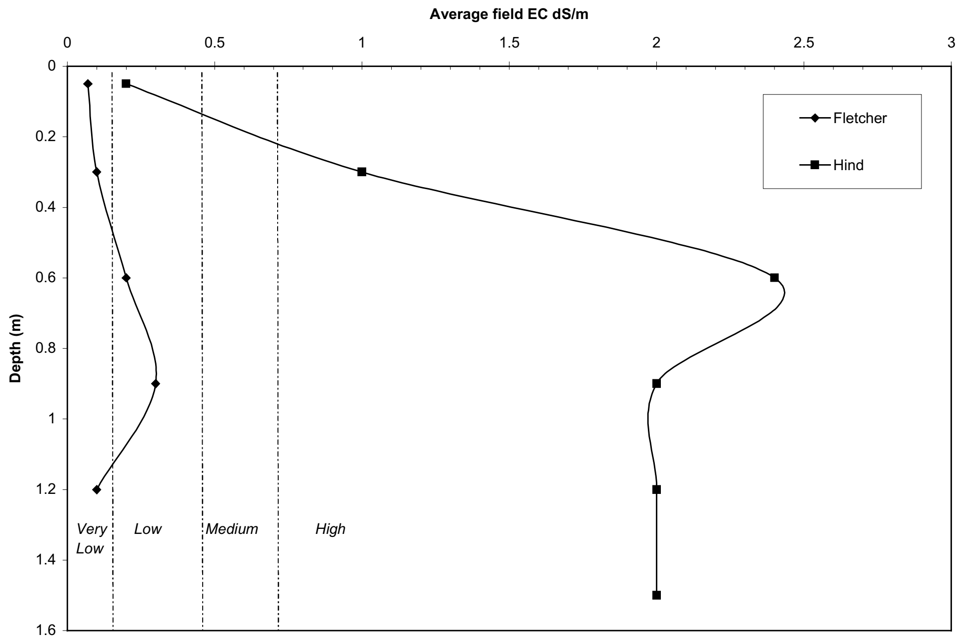


**Figure 10.** Average field EC values of soil types *Fletcher* and *Hind*

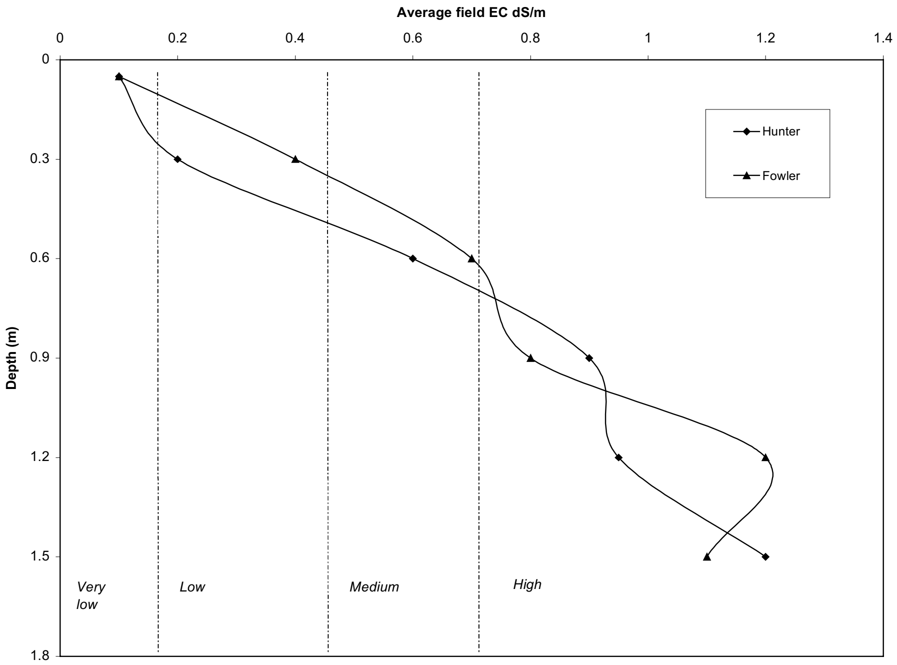


**Figure 11.** Average field EC values of soil types *Hunter* and *Fowler*

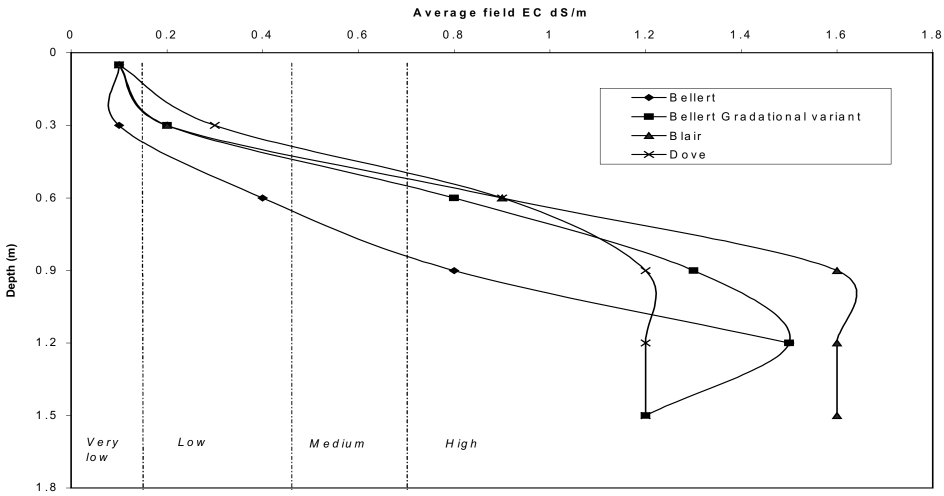


**Figure 12.** Average field EC values of soil types *Bellert*, *Bellert Gradational variant*, *Blair* and *Dove*

## Soil nutrients

The two main cropping soils within the Coalstoun Lakes area, *White* and *Witton*, have low levels of nitrogen and sulfur. Phosphorus levels are very high and trace elements are adequate in quantity. Other basaltic soils, *Hind* and *Fletcher* are low in nitrogen and trace elements. Phosphorus levels are adequate for native pastures, but low for improved pastures and cropping purposes.

*Witton* and *White*, are very low in potassium through out the profile. Nitrogen levels are also low, with levels continually decreasing due to the declining levels of organic matter.

*Blair* has a low supply of nitrogen, phosphorus, potassium and sulfur. Trace elements are adequate in supply.

The sodic texture contrast soil on alluvium (*Fowler*) has inadequate levels of total nitrogen, potassium, sulfur and phosphorus if these soils are to be used for cropping.

### Cation Exchange Capacity (CEC)

CEC is the measure of the capacity of a soil to hold the major cations; calcium, magnesium, sodium and potassium. It is a measure of the potential nutrient reserve in the soil and therefore an indication of inherent soil fertility. An imbalance in the ratio of cations can result in soil structural problems. The Vertosols (*Hind, Hunter* and *Dove*) have a high CEC (>40). This CEC reflects that the soils are 2:1 type clays, which have a high ability to hold nutrients. All these Vertosols are magnesium dominated.

The sodosols of the alluvial plains have medium CEC (10–30meq/100g). Magnesium is the dominant cation on the exchange.

The Ferrosols (*White* and *Witton*) have low CEC. This reflects that these soils are 1:1 type clay. They have a weak ability to hold nutrients. Throughout the profile calcium is the dominant cation. This reflects favourable soil properties such as structure, stability and pore space.

### PAWC

Plant available water capacity (PAWC) is the quantity of water held in a soil that can be extracted by plant roots. PAWC reflects rooting depth, textures, clay types and amount of coarse fragments. The PAWC for this survey was estimated from laboratory analysis of particle size and wilting point by using the method of Littleboy (1997).

The two Ferrosols have an effective rooting depth greater than one metre and in turn have a PAWC of 100 mm for 1.2 m.

*Fletcher* and *Dove* both have a PAWC of approximately 130 mm. *Fletcher* has a rooting depth of 0.9 m and *Dove* a rooting depth of only 0.5 m. The basaltic vertosol, *Hind*, which only has an effective rooting depth of 0.4 m, has a PAWC of just 79 mm.

The PAWC of the soils are related to the proportion of clay and type of clay within the soil profile. The montmorillonite type clays, *Dove*, *Hunter*, *Hind* and *Fletcher* have a higher water holding capacity than the kaolinite clays such as *Witton* and *White*. However, the PAWC is greatly reduced in *Dove* and *Hind* because of their shallow rooting depth induced by high salts and high sodicity.

# 5. Agricultural Land Evaluation

## 5.1 Current land use

The current land uses of the Coalstoun Lakes area consist of rainfed cropping, and minor dairying, irrigated cropping and grazing.

Peanuts (rainfed and irrigated), maize and sorghum are the main summer crops grown in the area, while wheat and barley are common winter crops grown.

A few dairies operate in the area, while the remaining uncropped land is used for grazing production.

## 5.2 Land suitability

Land suitability assessment provides an estimate of the potential of land for a particular form of land use. In Queensland, land is assessed on the basis of five land suitability classes with suitability decreasing from class 1 to 5 (Land Resources Branch Staff 1990). A short definition of the classes is as follows:

**Class 1** Suitable land with negligible limitations;
**Class 2** Suitable land with minor limitations;
**Class 3** Suitable land with moderate limitations;
**Class 4** Marginal land which is presently unsuitable due to severe limitations; and
**Class 5** Unsuitable land with extreme limitations.

Land resource information gathered during soil surveys, as well as the results of laboratory analyses on selected soil profiles, was used in assessing land suitability.

A total of 100 unique map areas (UMA) have been delineated. Each UMA has been assessed for its relative suitability for growing the following crops using the irrigated suitability classification scheme described in Appendix III:

Asparagus
Avocado
Beans
Chickpea
Citrus
Cotton
Cruciferae (such as broccoli and cauliflower)
Mango
Grapes
Improved pastures
Lucerne
Lychee
Macadamia
Low chill stone fruits
Cucurbits (such as melons, pumpkins and rockmelons)
Mungbean
Navybean
Pecan
Peanut
Potato
Safflower
Soybean
Sugar cane
Sunflower
Sweet corn
Sweet potato
Summer grains (such as maize and sorghum)
Vegetables (such as tomatoes, zucchini, capsicum)
Winter grains (such as wheat and barley)

Each UMA was also assessed for suitability for surface (furrow) irrigation.

The land suitability classification used was developed for a similar irrigation suitability assessments for the Bundaberg (Donnollan *et al.* 1998), Soils of the Riparian Lands of the Burnett River between Mundubbera and Gayndah, Queensland (Tucker and Sorby 1996) and for the Auburn River irrigation suitability study (Wilson and Sorby 1991).

Soil and land characteristics which cause land to have less than optimum conditions for a particular crop-irrigation method were recognised as limitations. Local soil and land attributes that provide a measure or an estimate of the effects of each limitation were then selected.

The degree of severity imposed by each limitation on a particular irrigated land use was ranked as a limitation, allowing an overall assessment of suitability.

## 5.3 Limitations to agriculture

Irrigated agriculture within the study area may be affected by the following limitations:

- Climate
- Water availability
- Wetness
- Soil depth
- Rockiness
- Microrelief
- Flooding
- Landscape complexity
- Topography
- Soil physical condition
- Secondary salinisation
- Erosion
- Furrow infiltration

The limitations affect crop production through influences on crop establishment and growth, on the use of machinery and may result in land degradation. A general description of each limitation is as given below:

### Climate

Except for the incidence of frosts, the climate does not vary significantly within the relatively small study area.

Plants vary in their tolerance to frosts. Frosts can suppress the growth of sensitive crops, kill plants or reduce yield through damage to flowers or fruits. Generally, the incidence and severity of frosts in the study is influenced by position in the landscape. Hill slopes and rises experience fewer and less severe frosts and are suitable for sensitive crops such as avocados and mangoes. The lower lying areas along the creeks and drainage lines may experience a regular occurrence of frosts. These affected areas limit the suitable crops to deciduous plants such as pecans, low-chill fruits, grapes, and adaptable small crops and field crops.

Local experience and variation in landform were used to determine the suitability subclasses for the various crops. Seasonal adaptation of crops is not considered, as for example, frost tolerance of summer crops.

## Water availability

Water availability refers to the limitation placed on crop yield by a restriction on soil water supply. For irrigated land, a reduced soil water storage capacity means more frequent irrigation is needed to obtain optimum yields.

Plant available water capacity (PAWC) provides the best estimate of a soil's storage capacity for irrigated land uses. PAWC is the difference in volumetric water content between the upper storage limit (approximately field capacity), and the lower storage limit (approximately wilting point) summed for each layer within the rooting depth of the soil and adjusted by the rooting profile over the rooting depth. Effective rooting depth is the depth to which approximately 90% of plant roots will extract water and this can be reduced by restrictive layers which are indicated by rock, consistency, pH, salinity peaks (measured by electrical conductivity), sodicity and segregations such as nodules.

The water availability limitation subclass is based on the frequency of irrigation required for optimal crop growth. Soils with high PAWC require less frequent irrigation if the profile is fully recharged.

A decision regarding when to irrigate and how much to apply may be determined by considering the soil water store, drainage below the root zone, runoff and amount of water used by the crop. By considering these factors crop productivity may be improved, water use efficiency is increased and the likelihood of drainage and salinity problems can be reduced.

## Wetness

Wetness refers to excessive water on the soil surface and in the soil profile as a result of rainfall or local run-on water. The excess water is caused by inadequate surface drainage and poor subsoil drainage and landscape position.

The wetness limitation takes into account the adverse effects of excess water on production through the reduction in crop growth and quality, restrictions in machinery use and the need for reclamation works.

Drainage classes (McDonald *et al.* 1990) are assessed and take into account all aspects of internal and external drainage in the existing state. The attributes used to indicate internal drainage include colour, mottles, segregations and impermeable layers. Red or brown whole colours indicate well drained soils while mottled grey soils with segregations, such as manganiferous nodules, indicate imperfect drainage. Slope and topographic position are used to assess the ease of disposal of excess water. Soil permeability, [indicated by texture, pedality, grade of structure, segregation, pH, ESP (exchangeable sodium percentage)], affects the supply and removal of soil water within the root zone.

Drainage within the study area is indicative by position within the landscape. The highly weathered, well drained basaltic soils, *White* and *Witton*, are found higher in the landscape. The lower lying basaltic soils, *Fowler* and *Hind* are imperfectly drained. The colluvial grey clay*, Dove*, occurs low in the landscape and may remain wet for periods of time.

## Soil depth

All crops require an adequate depth of soil to provide physical support for the aerial portion of the plant. Requirement for physical support will increase with crops that have large canopies such as tree crops. Uprooting of trees is particularly a problem on shallow, wet soils during windy conditions.

A majority of the soil types within Coalstoun Lakes have a depth ranging from moderate to very deep. *Bellert, Blair* non-vertic variant, and *Fletcher* shallow variant are all shallow soil types.

## Rockiness

Rock fragments within the plough layer will interfere with the use of, and possible cause damage to agricultural machinery thereby affecting crop planting depth. The volume of rock fragments within the soil is extremely variable and difficult to estimate for any particular map unit. The limitation increases with the increase in size and/or amount encountered. Tolerance levels will also vary between farmers and between different agricultural enterprises.

In general, crops which require several cultivations annually and have low harvest heights (chickpeas, navybeans, and soybean) have a low tolerance to rock. Root crops (potato, peanuts) are very sensitive. Horticultural tree crops can tolerate considerable amounts.

The size and amount of coarse fragment, as defined by McDonald *et al.* (1990), were used to determine the subclasses.

Rocks are consistently a problem for all soil types except the alluvial and colluvial soil types. Extensive soil picking operations have occurred in previous years to clear the basaltic soils for cropping purposes.

## Microrelief

Gilgai microrelief will affect the efficiency of irrigation, depressions will pond water causing uneven crop productivity. Areas with gilgai or other microrelief must be levelled to ensure even slopes for efficient water use, especially under furrow irrigation. Levelling of gilgai soils, which contain sodic and/or saline layers close to the surface, may expose the sodic or saline layers at the soil surface. The vertical interval of the microrelief, which effects the amount of levelling required, is used as a diagnostic attribute to determine subclass limits.

Gilgai is not extensive within the Coalstoun Lakes area. The colluvial soil type, *Dove*, may have weakly developed gilgai present.

## Flooding

Adverse effects of flooding are yield reduction or plant death through excessive flow velocity, flood water characteristics such as silt content and water temperature, lack of aeration and physical removal or damage of plants and soil because of flowing water. The effects on flooding on individual mapping units can not be predicted from this study. Landform position in relation to historical flood flows was used to make some distinction between suitable and unsuitable land.

Floods are mainly restricted to the narrow channel benches of Sandy Creek.

Crop damage depends on its susceptibility to flooding. Sugar cane is moderately tolerant of inundation and different varieties will vary. Horticultural crops, such as small crops (melons, pumpkins, tomatoes, and capsicums), avocadoes, papaws, pineapples, citrus and mangoes are very sensitive to flooding. Lychees are more tolerant and will withstand flooding for short periods. Other crops, such as maize, sorghum and soybeans are sensitive.

## Landscape complexity

This limitation assesses the effect of landscape complexity on irrigation management within individual map units and may be influenced by surrounding map units. To maximise irrigation efficiency, soil types within rows should have similar soil water holding capacity, infiltration attributes and management. If these soil properties are markedly different between soil types, productivity over the whole unit will be reduced because of ineffective irrigation scheduling and difficulty in timing for planting, cultural and harvesting operations.

Soil complexity is assessed for a particular crop and irrigation method on the size and isolation of the mapping unit and the compatibility of the soil types in surrounding units. Soil complexity has a greater influence on the suitability of land for cotton or peanuts than it does for citrus.

Where soils differ in their suitability, the suitability of the soils is downrated to the criteria relating to production area size and the type of agricultural enterprise.

## Topography

The topography limitation has a direct affect on the ease of machinery operations and land use efficiency in general. It covers the slope limits for the safe use of machinery.

The slope limit for the safe and efficient use of machinery is 15%. However all land greater than 15% in the study is unsuitable or marginal for agricultural development due to other limitations.

## Soil physical condition

Soil physical properties influence seedbed preparation, plant establishment and the harvest of root crops. The soil physical condition is related to properties such as surface condition, moisture range for working, and adhesiveness.

Surface condition of soils will effect seedling emergence and establishment, and root crop development through hardsetting, crusting and coarse structure. Adhesive soils affect the recoverability and condition of root crops such as peanuts. Peanut crops ideally require friable soils to enable harvesting machinery to easily lift and remove crops from the soil. A majority of the massive surfaced clay loam soils or poorly to imperfectly drained soils with clay textured surfaces are adhesive to varying degrees. In general, the degree of adhesiveness increases as clay content and/or consistency increase and degree of pedality decreases (Wilson 1991).

Tillage operations may be successfully completed at specific soil moisture ranges. The clay soils, *Dove* and *Hunter*, have a narrow moisture range for tillage while the hardsetting fine loamy surface soils have a moderate moisture range.

### Secondary salinisation

Clearing and irrigation can change the hydrology of the landscape to some extent. Less water is intercepted by trees, and increased percolation of water can cause seepage outbreaks lower down the slope. This excess water can bring salts from the subsoil to the surface resulting in secondary salinasation. This process is exacerbated where permeable soils occupy upper slope positions and slowly permeable soils occur on lower slopes and valley floors.
Areas where excess water enters the landscape are called recharge areas. Areas where water rises to the surface or close to the surface against an impermeable barrier or change in slope are called discharge areas.

The slowly to very slowly permeable heavier clay soils (*Dove*, *Hunter* and *Fletcher)* surrounding the highly permeable red Ferrosols (*White* and *Witton)* are soil types at high risk of salinisation outbreaks if excess water is applied to the recharge areas.

### Erosion

Water erosion causes soil degradation and long-term productivity decline. Land subject to moderate to severe water erosion will not support sustainable cropping. Crop damage, higher working costs, uneven harvest heights, damage caused by silt deposition and fertility decline also result from soil erosion.

The severity of soil erosion by flowing water is governed by climatic factors such as the amount, distribution and intensity of rainfall, landform factors such as gradient and slope length, soil erodibility and management practices such as maintaining surface cover.

Tree crops such as citrus have higher slope limits than other broadacre crops because of the reduced cultivation and increased surface cover.

### Furrow infiltration

The irrigation system and field layout should be tailored to the permeability of each soil. For furrow irrigation, long furrow lengths and application times are inappropriate for soils where a significant deep drainage component is likely to occur. This causes excess infiltration, leaching, seepage, wastage of water, and problems with aeration at he head ditch end of the furrows. Furrow irrigation is suitable only on land with gentle slopes and slowly permeable soils, such as cracking clays soils and texture contrast soils. Spray, micro/sprinklers or drip irrigation should be used on permeable and sloping soils for even application of water, and to minimise deep drainage and thus avoid off-site seepage and watertable rises.

## 5.4 Discussion

A summary of the suitability of each soil type for the agricultural and horticultural crops assessed are shown in Table 3.

The soil types *White* and *Witton* constitute approximately 50% (4000 ha) of the total area mapped. In the remaining area, 25% of the area is soils developed on alluvium (1900 ha), and soils formed on Biggenden Beds (765 ha) have slopes greater than 8%.

The Red Ferrosols, *White* and *Witton*, are suitable for a wide range of irrigated agricultural and horticultural crops. The highly permeable nature of these soils restricts them from being suitable for furrow irrigation systems. They are more suited to overhead spray or trickle/microspray irrigation systems. Areas of these soil types where surface rocks are abundant, restrict the potential for cropping.

The Sodosol, *Sandy*, is suited for cropping a majority of the crops assessed. This soil type is sometimes prone to flooding, depending on position in the landscape. The flooding limitation causes this soil to be unsuitable for crops such as pineapples and most tree crops. The other alluvial Sodosol, *Fowler*, also lends itself to irrigated cropping of wetness tolerant crops, except in areas where surface rocks dominate.

Poor drainage and very slow permeability prevents the *Dove* soil type from being suitable for any future cropping development.

The soils formed on Biggenden Beds vary in their suitability for the crops assessed. Slope and rockiness are the most common limitations which render these soils unsuitable to grow crops.

Figure 4 summarises the area of land suitable (class 1, 2 and 3) for each of the crops assessed. A total of 6290 ha suitable for sugarcane, 5793 ha for asparagus, cruciferae and vegetables, 5713 ha for beans, 5793 ha for cucurbits, 4190 ha for lucerne, 5580 ha suitable for navybean and potato, 4596 ha for sorghum, 4418 ha for soybean, 4596 ha for sweet corn, 5660 ha for sweet potato, 6281 ha for avocado, macadamia, citrus, lychee and mango, 4325 ha for grapes, 4289 ha for stonefruit, 4781 ha for peanuts, 4596 ha for maize and 6591 ha for pasture. Furrow irrigation of sugarcane is suitable on only 1284 ha of land.

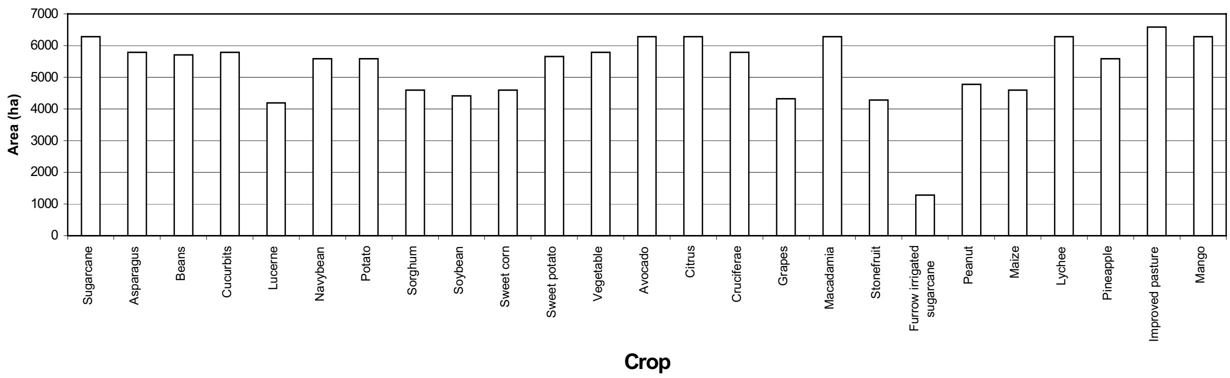


**Figure 13.** Area of land which is potentially suitable for each crop assessed

**Table 3. Areas of land suitability classes for crops in each mapping unit**

| Soil type | suitability | sugarcane | asparagus | beans | cucurbits | lucerne | navybean | potato | sorghum | soybean | sweet corn | sweet potato | vegetable | avocado | citrus | cruciferae | grapes | macadamia | stonefruit | Furrow Irrigation sugarcane | peanut | maize | lychee | pineapple | Pasture Suitability | mango |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bl | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | 77.3 | 4.6 | 4.6 | 4.6 | | | | | | | | 4.6 | 303.7 | 303.7 | 4.6 | | 303.7 | | 4.6 | | | 303.7 | 4.6 | 303.7 | 303.7 |
| | 4 | 226.4 | 72.7 | | 72.7 | 226.4 | 4.6 | 4.6 | 77.3 | 4.6 | 77.3 | 77.3 | 72.7 | | | 72.7 | 226.4 | | 226.4 | 72.7 | 4.6 | 77.3 | | 72.7 | | |
| | 5 | | 226.4 | 299.1 | 226.4 | 77.3 | 299.1 | 299.1 | 226.4 | 299.1 | 226.4 | 226.4 | 226.4 | | | 226.4 | 77.3 | | 77.3 | 226.4 | 299.1 | 226.4 | | 226.4 | | |
| BlGv | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | | | | | | | | 51 | | 51 | | | 51 | 51 | | 51 | 51 | 51 | | | 51 | 51 | 51 | | 51 |
| | 3 | 208.9 | 51 | 51 | 51 | 51 | | | | 51 | | | 51 | 192.3 | 192.3 | 51 | | 192.3 | | | | | 192.3 | | 243.3 | 192.3 |
| | 4 | | 157.9 | | 157.9 | | 51 | 51 | 157.9 | | 157.9 | 208.9 | 157.9 | | | 157.9 | 34.4 | | 34.4 | 157.9 | 51 | 157.9 | | 157.9 | | |
| | 5 | 34.4 | 34.4 | 192.3 | 34.4 | 192.3 | 192.3 | 192.3 | 34.4 | 192.3 | 34.4 | 34.4 | 34.4 | | | 34.4 | 157.9 | | 157.9 | 85.4 | 192.3 | 34.4 | | 34.4 | | |
| Br | 1 | 1.4 | | | | | | | 1.4 | | | | | 6.9 | 6.9 | | | 6.9 | | | | 1.4 | 6.9 | 6.9 | 6.9 | 6.9 |
| | 2 | 5.5 | 1.4 | 1.4 | 1.4 | 1.4 | | | 5.5 | 1.4 | 6.9 | | 1.4 | 40.6 | 40.6 | 1.4 | 47.5 | 40.6 | 47.5 | | | 5.5 | 40.6 | | 40.6 | 40.6 |
| | 3 | 115.9 | 80.8 | 80.8 | 80.8 | 46.1 | 76.7 | 76.7 | | 5.5 | | 76.7 | 80.8 | 161.7 | 161.7 | 80.8 | 25.3 | 161.7 | 25.3 | 75.3 | 1.4 | | 161.7 | 75.3 | 161.7 | 161.7 |
| | 4 | 86.4 | 40.6 | 40.6 | 40.6 | 86.4 | 46.1 | 46.1 | 115.9 | 115.9 | 115.9 | 46.1 | 40.6 | | | 40.6 | 61.1 | | 61.1 | | 121.4 | 115.9 | | 40.6 | | |
| | 5 | | 86.4 | 86.4 | 86.4 | 75.3 | 86.4 | 86.4 | 86.4 | 86.4 | 86.4 | 86.4 | 86.4 | | | 86.4 | 75.3 | | 75.3 | 133.9 | 86.4 | 86.4 | | 86.4 | | |
| BrNVv | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 5.4 | | | | | | | | | | | | 5.4 | 5.4 | | | 5.4 | | | | | 5.4 | | 5.4 | 5.4 |
| | 3 | | 5.4 | 5.4 | 5.4 | | | | 5.4 | 5.4 | 5.4 | | 5.4 | | | 5.4 | | | | | | 5.4 | | 5.4 | 13.2 | |
| | 4 | | | | | 5.4 | 5.4 | 5.4 | | | | 5.4 | | 13.2 | 13.2 | | 15.9 | 13.2 | 15.9 | 5.4 | 5.4 | | 13.2 | | | 13.2 |
| | 5 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | | | 13.2 | 2.7 | | 2.7 | 13.2 | 13.2 | 13.2 | | 13.2 | | |
| Cr | 1 | | | | | | | | | | | | | | | | | | | | | | | | 28.1 | |
| | 2 | 28.1 | | | | | | | | | | | | 31.6 | 31.6 | | | 31.6 | | | | | 31.6 | | 31.6 | 31.6 |
| | 3 | 31.6 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 59.7 | 28.1 | 59.7 | | | 28.1 | 28.1 | 28.1 | | 28.1 |
| | 4 | | 31.6 | | 31.6 | 31.6 | | | 31.6 | | 31.6 | | 31.6 | | | 31.6 | | | | 28.1 | 28.1 | 31.6 | | 31.6 | | |
| | 5 | 76.5 | 76.5 | 108.1 | 76.5 | 76.5 | 108.1 | 108.1 | 76.5 | 108.1 | 76.5 | 108.1 | 76.5 | 76.5 | 76.5 | 76.5 | 76.5 | 76.5 | 76.5 | 108.1 | 108.1 | 76.5 | 76.5 | 76.5 | 76.5 | 76.5 |
| Dv | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 44.9 | 44.9 | 44.9 | 44.9 | | 44.9 | | | | | | 44.9 | 44.9 | 44.9 | 44.9 | | 44.9 | | | | | 44.9 | 44.9 | 44.9 | 44.9 |
| | 3 | 359.7 | 285.4 | 285.4 | 285.4 | | 219.1 | 264 | 44.9 | 44.9 | 44.9 | 264 | 285.4 | 359.7 | 359.7 | 285.4 | | 359.7 | | 285.4 | | 44.9 | 359.7 | 285.4 | 285.4 | 359.7 |
| | 4 | 283.8 | 358.1 | 358.1 | 358.1 | 44.9 | 424.4 | 424.4 | 359.7 | 359.7 | 359.7 | 424.4 | 358.1 | 283.8 | 283.8 | 358.1 | 44.9 | 283.8 | 44.9 | 403 | 688.4 | 359.7 | 283.8 | 358.1 | 358.1 | 358.1 |
| | 5 | 136.3 | 136.3 | 136.3 | 136.3 | 779.8 | 136.3 | 136.3 | 420.1 | 420.1 | 420.1 | 136.3 | 136.3 | 136.3 | 136.3 | 136.3 | 779.8 | 136.3 | 779.8 | 136.3 | 136.3 | 420.1 | 136.3 | 136.3 | 136.3 | 136.3 |

**Table 3 (continued)**

| soil type | suitability | sugarcane | asparagus | beans | cucurbits | lucerne | navybean | potato | sorghum | soybean | sweet corn | sweet potato | vegetable | avocado | citrus | cruciferae | grapes | macadamia | stonefruit | Furrow Irrigation sugarcane | peanut | maize | lychee | pineapple | Pasture Suitability | mango |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fl | 1 | 145.7 | | | | | | | | | | | | 145.7 | 145.7 | | | 145.7 | | | | | 145.7 | | 216.6 | 145.7 |
| | 2 | 146.2 | 291.9 | 291.9 | 291.9 | 145.7 | | | 239.3 | 239.3 | 239.3 | | 291.9 | 180.2 | 180.2 | 291.9 | 153.3 | 180.2 | 153.3 | | | 239.3 | 180.2 | 325.9 | 146.2 | 180.2 |
| | 3 | 70.9 | | | | 93.6 | 291.9 | 291.9 | 123.5 | 52.6 | 123.5 | 291.9 | | | | | 156.9 | | 120 | | 291.9 | 123.5 | | 36.9 | | |
| | 4 | | 70.9 | 70.9 | 70.9 | 123.5 | | | | 70.9 | | | 70.9 | 36.9 | 36.9 | 70.9 | 52.6 | 36.9 | 89.5 | 209.5 | | | 36.9 | | | 36.9 |
| | 5 | | | | | | 70.9 | 70.9 | | | | 70.9 | | | | | | | | 153.3 | 70.9 | | | | | |
| FlSv | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | | | | | | | | | | | | | 14.6 | |
| | 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | | 14.6 |
| Fw | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 148.5 | 148.5 | 55.8 | 148.5 | | | | | | | | 148.5 | 148.5 | 148.5 | 148.5 | | 148.5 | | | | | 148.5 | 148.5 | | 148.5 |
| | 3 | 554.4 | 554.4 | 647.1 | 554.4 | | 702.9 | 702.9 | 148.5 | 148.5 | 148.5 | 702.9 | 554.4 | 554.4 | 554.4 | 554.4 | | 554.4 | | 554.4 | 702.9 | 148.5 | 554.4 | 554.4 | 702.9 | 554.4 |
| | 4 | 34.3 | 34.3 | 34.3 | 34.3 | 148.5 | 34.3 | 34.3 | 554.4 | 554.4 | 554.4 | 34.3 | 34.3 | 58.8 | 58.8 | 34.3 | 173 | 58.8 | 173 | 182.8 | 34.3 | 554.4 | 58.8 | 34.3 | 58.8 | 58.8 |
| | 5 | 24.5 | 24.5 | 24.5 | 24.5 | 613.2 | 24.5 | 24.5 | 58.8 | 58.8 | 58.8 | 24.5 | 24.5 | | | 24.5 | 588.7 | | 588.7 | 24.5 | 24.5 | 58.8 | | 24.5 | | |
| Hd | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | 63.4 | 63.4 | 63.4 | 63.4 | | 63.4 | 63.4 | | | | 63.4 | 63.4 | 63.4 | 63.4 | 63.4 | | 63.4 | | 63.4 | | | 63.4 | 63.4 | 63.4 | 63.4 |
| | 4 | | | | | | | | 63.4 | 63.4 | 63.4 | | | | | | | | | | 63.4 | 63.4 | | | | |
| | 5 | 136.4 | 136.4 | 136.4 | 136.4 | 199.8 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 199.8 | 136.4 | 199.8 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 | 136.4 |
| Hu | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 56.4 | 56.4 | 56.4 | 56.4 | | 56.4 | | | | | | 56.4 | 56.4 | 56.4 | 56.4 | | 56.4 | | | | | 56.4 | 56.4 | 56.4 | 56.4 |
| | 3 | 287.3 | 287.3 | 287.3 | 287.3 | | 287.3 | 343.7 | 56.4 | 56.4 | 56.4 | 343.7 | 287.3 | | | 287.3 | | | | 287.3 | | 56.4 | | | 287.3 | |
| | 4 | | | | | 56.4 | | | 287.3 | 287.3 | 287.3 | | | | | | 56.4 | | 56.4 | 56.4 | 343.7 | 287.3 | | | | |
| | 5 | 6.6 | 6.6 | 6.6 | 6.6 | 293.9 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 293.9 | 293.9 | 6.6 | 293.9 | 293.9 | 293.9 | 6.6 | 6.6 | 6.6 | 293.9 | 293.9 | 6.6 | 293.9 |
| Sd | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 27.7 | 27.7 | 27.7 | 27.7 | | 27.7 | 27.7 | | | | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | | 27.7 | | | 27.7 | | 27.7 | 27.7 | 59.8 | 27.7 |
| | 3 | 32.1 | 32.1 | 32.1 | 32.1 | 32.1 | 32.1 | 32.1 | 59.8 | 59.8 | 59.8 | 32.1 | 32.1 | | | 32.1 | | | | | 32.1 | 59.8 | | | | |
| | 4 | | | | | 27.7 | | | | | | | | | | | 27.7 | | 27.7 | 27.7 | | | | | | |
| | 5 | | | | | | | | | | | | | 32.1 | 32.1 | | 32.1 | 32.1 | 32.1 | 32.1 | | | 32.1 | 32.1 | | 32.1 |

**Table 3 (continued)**

| soil type | suitability | sugarcane | asparagus | beans | cucurbits | lucerne | navybean | potato | sorghum | soybean | sweet corn | sweet potato | vegetable | avocado | citrus | cruciferae | grapes | macadamia | stonefruit | Furrow Irrigation sugarcane | peanut | maize | lychee | pineapple | Pasture Suitability | mango |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wh | 1 | 1730.4 | | | | | | | 1628.1 | | | | | 1593.1 | 1593.1 | | 854.1 | 1593.1 | 716.8 | | | 1628.1 | 1593.1 | 1628.1 | 1751.9 | 1593.1 |
| | 2 | | 1730.4 | 1730.4 | 1730.4 | 1730.4 | | | 102.3 | 1730.4 | 1730.4 | | 1730.4 | 158.8 | 158.8 | 1730.4 | 897.8 | 158.8 | 1035.1 | | | 102.3 | 158.8 | 123.8 | | 158.8 |
| | 3 | 45.7 | 24.2 | 24.2 | 24.2 | | 1754.6 | 1754.6 | 21.5 | | 21.5 | 1754.6 | 24.2 | 24.2 | 24.2 | 24.2 | | 24.2 | | | 1730.4 | 21.5 | 24.2 | 24.2 | 24.2 | 24.2 |
| | 4 | | 21.5 | 21.5 | 21.5 | 21.5 | | | | 21.5 | | | 21.5 | | | 21.5 | | | | 24.2 | 24.2 | | | | | |
| | 5 | | | | 0 | 24.2 | 21.5 | 21.5 | 24.2 | 24.2 | 24.2 | 21.5 | | | | | 24.2 | | 24.2 | 1751.9 | 21.5 | 24.2 | | | | |
| Wt | 1 | 338.8 | | | | | | | 338.8 | | | | | 1777.2 | 1777.2 | | 1961.2 | 1777.2 | 1777.2 | | | 338.8 | 1777.2 | 338.8 | 1961.2 | 1777.2 |
| | 2 | 1622.4 | 1961.2 | 338.8 | 1961.2 | 1961.2 | | | 1622.4 | 338.8 | 1961.2 | | 1961.2 | 184 | 184 | 1961.2 | | 184 | 184 | | | 1622.4 | 184 | 1622.4 | | 184 |
| | 3 | | | 1622.4 | | | 1961.2 | 1961.2 | | 1622.4 | | 1961.2 | | | | | | | | | 1961.2 | | | | | |
| | 4 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 2100.8 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 | 139.6 |
| WtVv | 1 | 33.5 | | | | | | | 33.5 | | | | | 33.5 | 33.5 | | 33.5 | 33.5 | 33.5 | | | 33.5 | 33.5 | 33.5 | 118.6 | 33.5 |
| | 2 | 66.5 | 33.5 | 33.5 | 33.5 | 33.5 | | | | 33.5 | 33.5 | | 33.5 | 85.1 | 85.1 | 33.5 | | 85.1 | | | | | 85.1 | | | 85.1 |
| | 3 | 18.6 | 66.5 | | 66.5 | 66.5 | 33.5 | 33.5 | 85.1 | | 85.1 | 100 | 66.5 | | | 66.5 | 85.1 | | 85.1 | | 33.5 | 85.1 | | 85.1 | | |
| | 4 | | 18.6 | 85.1 | 18.6 | 18.6 | 66.5 | 66.5 | | 85.1 | | | 18.6 | | | 18.6 | | | | 85.1 | 66.5 | | | | | |
| | 5 | | | | | | 18.6 | 18.6 | | | | 18.6 | | | | | | | | 33.5 | 18.6 | | | | | |

## 5.5 Management and development issues

The possibility of future salinisation in some areas may affect future irrigation within the Coalstoun Lakes area. Widespread irrigation development of the highly permeable Red Ferrosols may cause seepage downslope with localised or general rises in watertables where these more permeable soils contact with less permeable soils such as *Fletcher* and *Hind*. There is evidence of minor seepage (<10 ha) occurring in these areas even under rainfed conditions. Any future irrigation systems will have to be designed so as to ensure that the amount of water being applied does not exceed crop uptake needs. It would be appropriate to establish monitoring sites throughout the area to monitor application rates, plant use and watertable levels.

Intensively cropping Red Ferrosol soils such as *Witton* and *White*, may lead to physical and chemical decline of these soils. The non-swelling nature of Ferrosols means they have no capacity for self-repair. Changes associated with structural decline and compaction include:

- reduced porosity and so reduced aeration and soil water storage;
- reduced infiltration resulting in increased runnoff and soil erosion;
- poorer drainage and reduced trafficability;
- increased mechanical root impedance due to increased soil strength and plough pan formation; and
- increased cloddiness.

Results from various studies on the decline of Ferrosols has indicated that a vigorous grass pasture, which can provide roots that can permeate soil, encourage soil fauna such as earthworms to create macropores, and provide carbon for structural stability may be the best form of repair.

Long-term cropping may also result in acidification and nutrient depletion in both the surface and subsoil. Moody *et al.* (1997) suggests the maintenance or enhancement of organic matter levels will promote the sustainable use of Ferrosols, maintenance of surface and subsoil pH and minimisation of erosion. It also requires the replacement of nutrients at rates that are equal to their removal in harvested products. Organic matter can to some extent be manipulated by management, and will determine such important properties as nutrient holding capacity and lime requirements.

Farming practises recommended for minimising acidification include:

- more closely matching fertiliser inputs to crop demand;
- using alternative (nitrate) forms of nitrogen fertiliser
- efficient irrigation management to minimise leaching;
- early sowing after fallow to minimise nitrate leaching;
- growing deep-rooting perennial species to minimise nitrate leaching; and
- regular applications of lime to counter the acidification inherent in the agricultural system.

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## Appendix I

## Soil Profile Classes

# Bellert

**Concept:** Grey or brown clay loam surface over red light medium clay. Abundant coarse fragments throughout the profile

**Australian Classification:** Red Sodosol

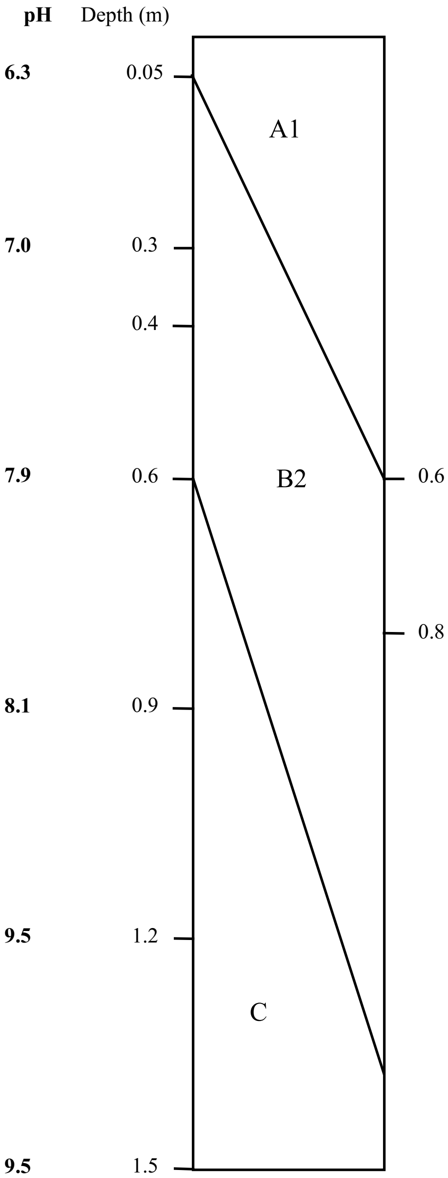
**Great Soil Group:** Solodic soil

**Principle Profile Form:** Dr2.13

**Geology:** Biggenden Beds

**Landform:** Hillslopes

**Vegetation:** Cleared




A1: Greyish brown or dark brown (7.5YR4/2, 3/3); clay loam; moderately coarse gravely; massive to weakly subangular blocky structure field pH 6.0 to 7.0. Abrupt change to -

B2: Dull reddish brown or reddish brown (5YR5/4, 4/4, 4/6); medium clay; strong subangular blocky structure; few manganiferious nodules; abundant coarse gravel; field pH 7.0 to 9.0

C: Weathered rock

**Bellert gadational variant**

Same as above with a gradual texture change between the A1 and B2.

## Blair

**Concept:** Red or Brown non-cracking clay soil, vertic structure at depth, formed on Biggenden Beds

**Australian Classification:** Red Dermosol

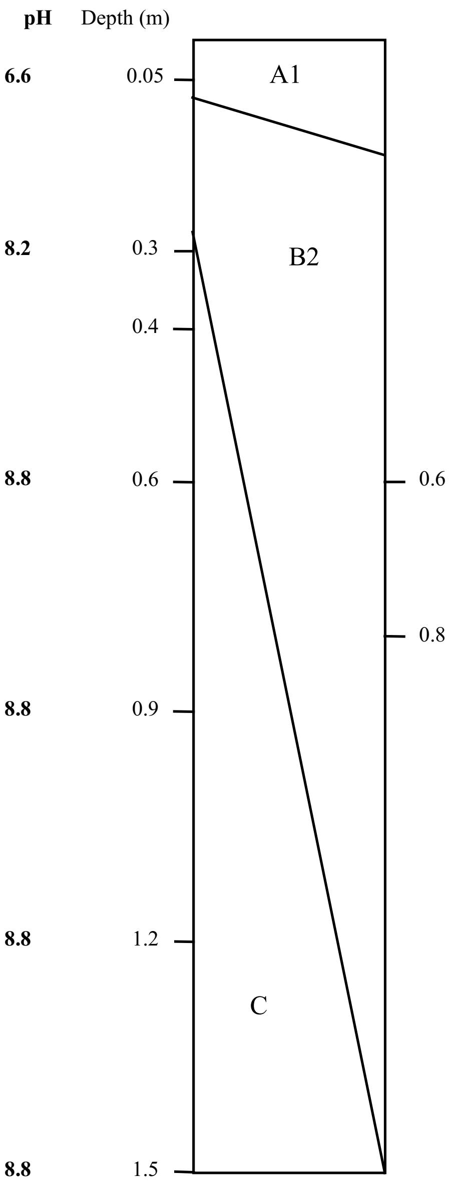
**Great Soil Group:** Prairie Soil

**Principle Profile Form:** Gn3.13

**Geology:** Biggenden Beds

**Landform:** Rises

**Vegetation:** Cleared




A1: Dull reddish brown or dark brown (5YR4/3, 7.5YR3/4) light medium clay to medium clay; strong fine subangular blocky structure; field pH 6.5 to 7.5. Clear to -

B2: Dull reddish brown or brown (5YR4/4, 7.5YR4/4); medium clay to medium heavy clay; moderate to strong lenticular structure; few manganiferious nodules; field pH 8.0 to 9.0.

C: Weathered rock

**Blair non-vertic variant**

Same as above except subsoil has moderate polyhedral structure and soil depth is generally less than 0.5 m.

# Crater

**Concept:** Black non-cracking clay on footslopes of Volcanoes

**Australian Classification:** Black Ferrosol

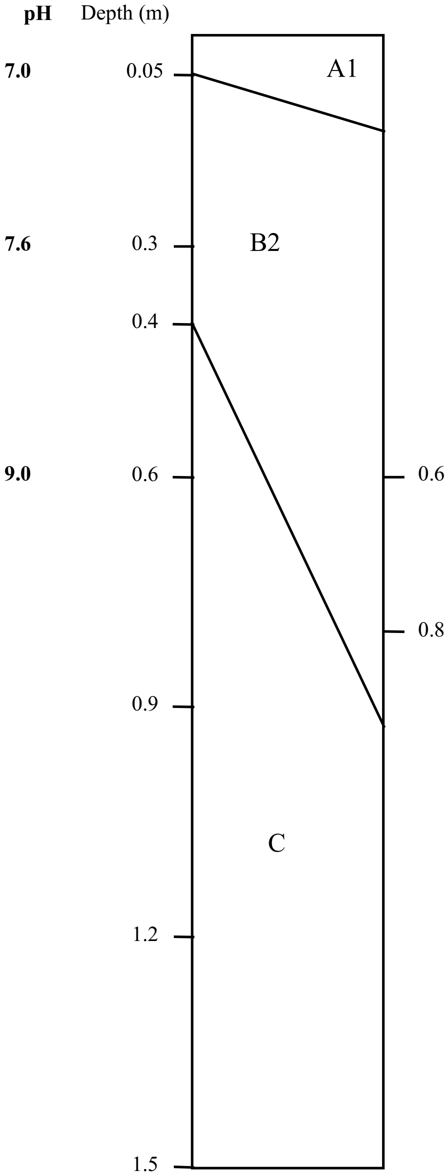
**Great Soil Group:** Prairie Soil

**Principle Profile Form:** Gn3.13

**Geology:** Barambah Basalt

**Landform:** Volcano

**Vegetation:** Cleared, minor softwood scrub




A1: Brownish black (5YR3/1); medium clay; strong polyhedral structure; field pH 7.0. Clear to -

B2: Brownish black (7.5YR3/2); medium clay to medium heavy clay; strong lenticular structure; field pH 7.0 to 9.0

C: Weathered Basalt

## Dove

**Concept:** Grey cracking clay soils on undulating plains on colluvial deposits

**Australian Classification:** Grey Vertosol

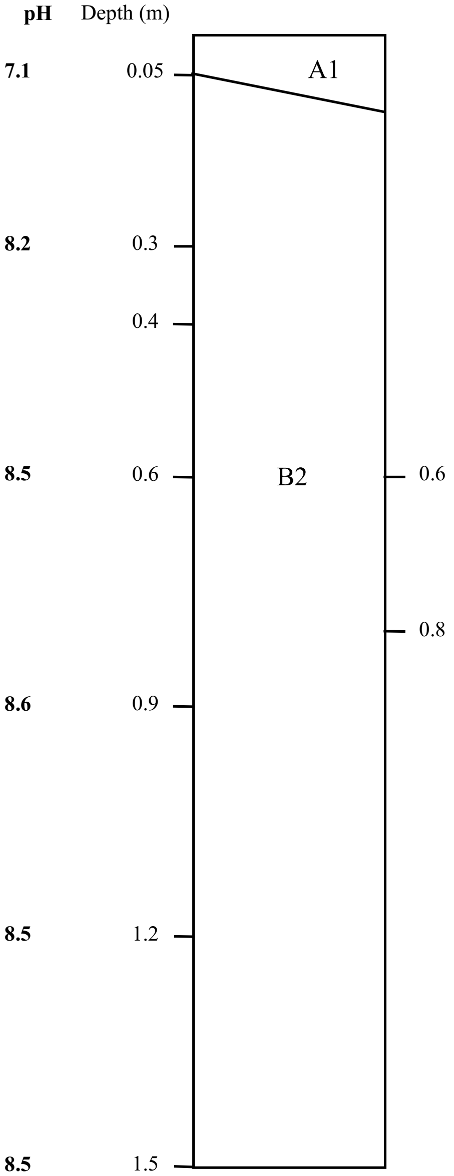
**Great Soil Group:** Grey Clay

**Principle Profile Form:** Ug5.24

**Geology:** Colluvial deposits derived from Biggenden Beds

**Landform:** Plains, drainage depressions

**Vegetation:** Brigalow, mostly cleared




A1: Brownish black (10YR3/1); medium clay to medium heavy clay; strong granular structure; field pH 7.0 to 8.5. Abrupt change to -

B2: Brownish grey (10YR4/1, 5/1); medium heavy clay to heavy clay; strong lenticular structure; few carbonate nodules; pH 9.0 to 9.5

# Fletcher

**Concept:** Brown non-cracking clay on undulating plains

**Australian Classification:** Brown Dermosol

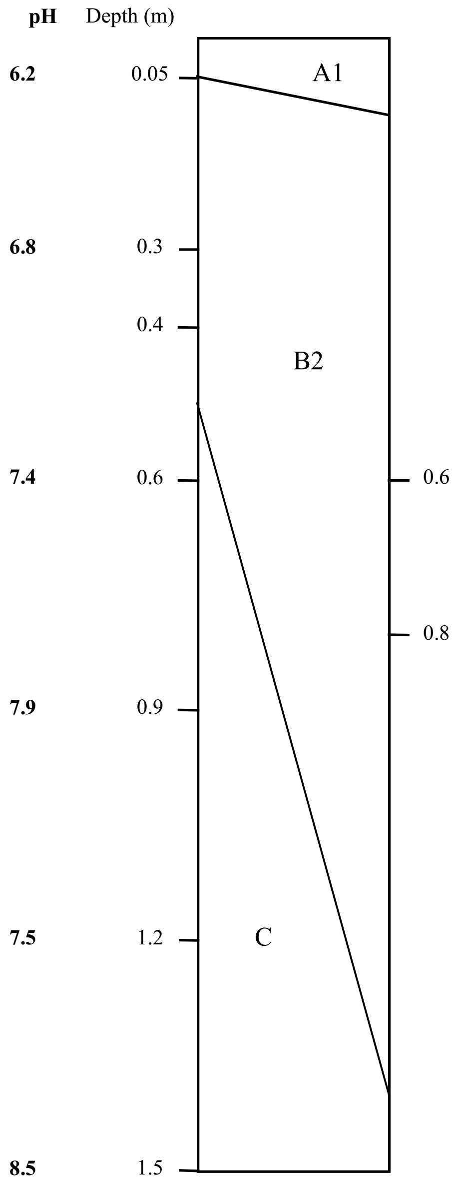
**Great Soil Group:** Prairie soil

**Principle Profile Form:** Uf6.31

**Geology:** Barambah Basalt

**Landform:** Gently undulating plains

**Vegetation:** Open *Eucalyptus* forest, mostly cleared




A1: Dark brown or greyish black (7.5YR3/3, 3/1, 10YR3/1); light clay to light medium clay; granular to strong fine subangular blocky structure; field pH 5.5 to 7.0. Clear change to -

B2: Dull yellowish brown, brown or brownish black (10YR5/4, 4/3, 4/4, 3/2); light clay to light medium clay; strong subangular blocky structure to moderate lenticular; field pH 7.0-8.5

C: Weathered rock

# Fowler

**Concept:** Thin surfaced texture contrast soil on alluvial plains

**Australian Classification:** Grey Sodosol

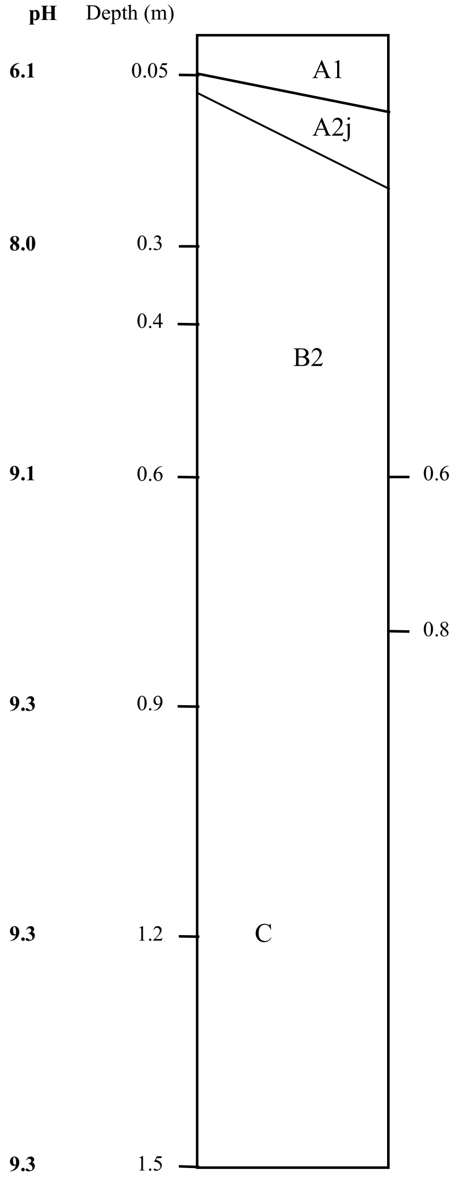
**Great Soil Group:** Solodic soil

**Principle Profile Form:** Dy2.33

**Geology:** Quaternary alluvia

**Landform:** Alluvial plains

**Vegetation:** Cleared




A1: Brownish black (10YR3/1, 3/2); fine sandy clay loam to clay loam sandy; massive to weakly granular structure; very few manganiferious nodules; pH 5.8 to 7.0. Abrupt change to -

A2j Dull brown or greyish yellow brown (7.5YR5/3, 10YR5/2); fine sandy loam to clay loam; very few manganiferious nodules; field pH 6.5. Abrupt change to -

B2: Brown or greyish yellow brown (10YR4/4, 4/2, 5/2, 6/2); light medium clay to medium clay; moderately subangular blocky to strong lenticular structure; few manganiferious nodules; field pH 8.0 to 9.3

## Hind

**Concept:** Black cracking clay soil on lower edge of basalt flows

**Australian Classification:** Black Vertosol

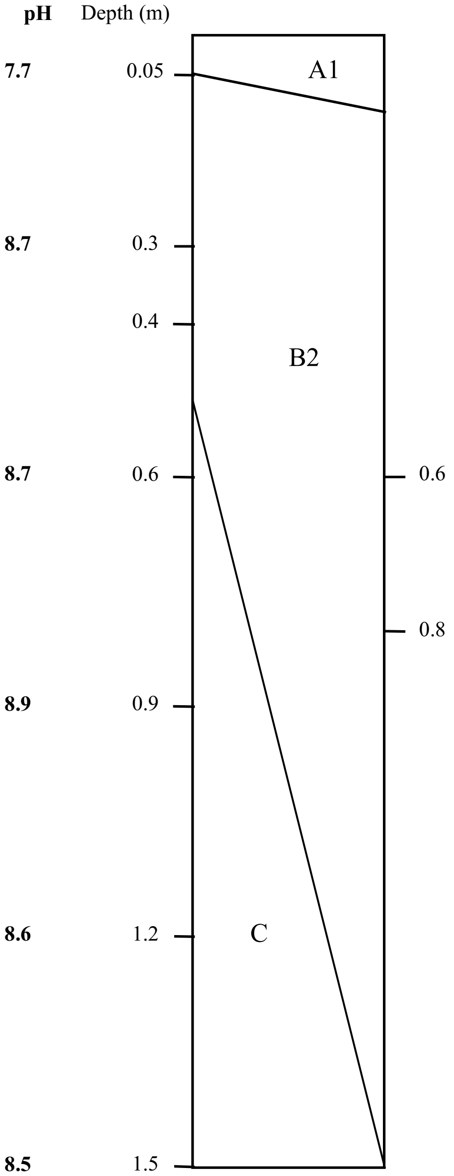
**Great Soil Group:** Black earth

**Principle Profile Form:** Ug5.1

**Geology:** Barambah Basalt

**Landform:** Undulating plains

**Vegetation:** Cleared




A1: Brownish black (10YR3/1); medium heavy clay to heavy clay; strong granular structure; few carbonate nodules; field pH 9.5. Abrupt change to -

B2: Brownish black becoming dark greyish yellow at depth (10YR3/1, 2.5Y5/2); medium to medium heavy clay; few to common carbonate nodules; field pH 8.5 to 9.0

C: Weathered rock

# Hunter

**Concept:** Black cracking clay soil on alluvial plains

**Australian Classification:** Black Vertosol

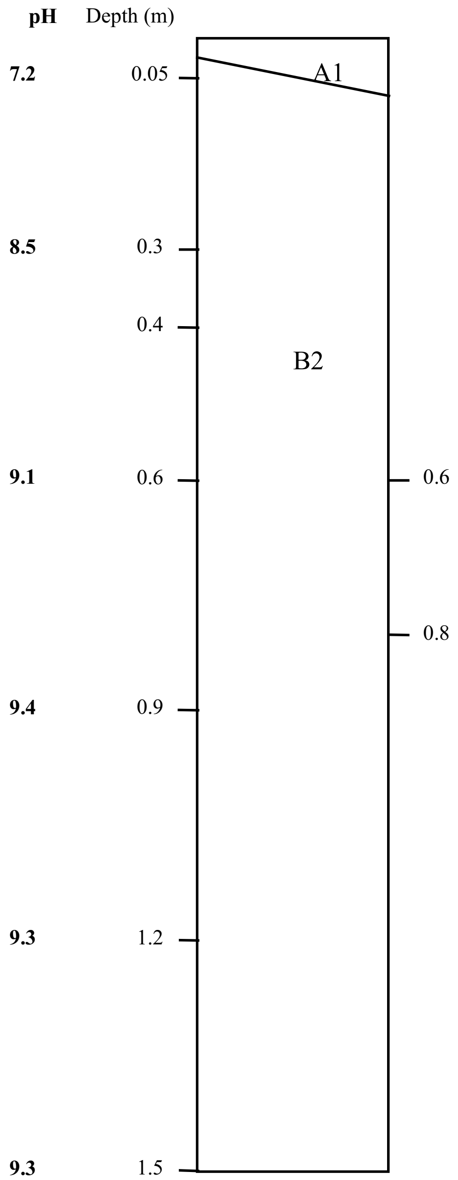
**Great Soil Group:** Black earth

**Principle Profile Form:** Ug5.1

**Geology:** Quaternary Alluvia

**Landform:** Alluvial plains

**Vegetation:** *Eucalyptus* forest, mostly cleared




A1: Greyish brown or brownish black (7.5YR4/2, 3/2, 10YR3/2); light clay to light medium clay; strong granular to strong fine subangular blocky; field pH 6.5 to 7.5. Abrupt change to -

B2: Brownish black, brownish grey or grey yellow brown (7.5YR4/2, 10YR4/1, 4/2, 5/2); light medium clay to medium heavy clay; strong lenticular structure; few carbonate nodules; field pH 8.3 to 9.5

## Sandy

**Concept:** Sandy surfaced texture contrast soil on alluvium

**Australian Classification:** Brown Sodosol

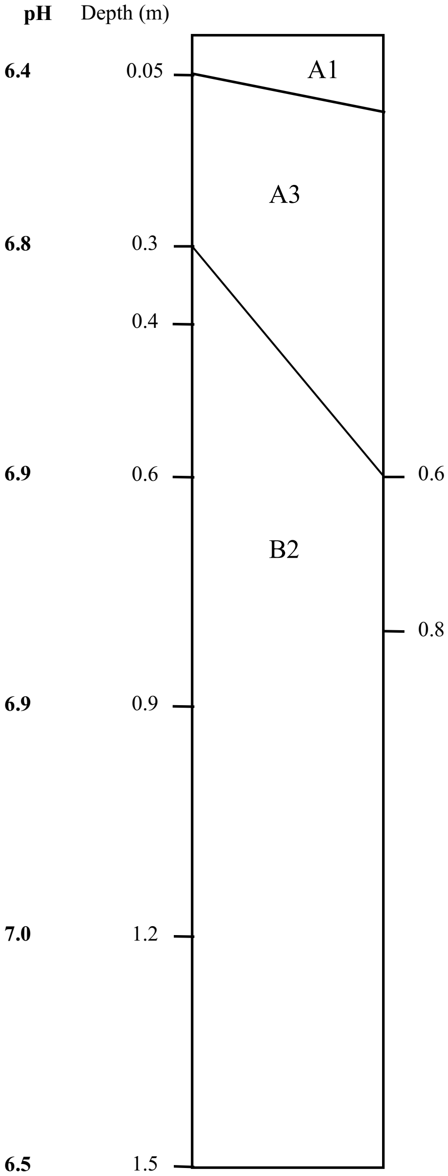
**Great Soil Group:** Solodic soil

**Principle Profile Form:** Dr4.12, Db3.12

**Geology:** Quaternary alluvia

**Landform:** Alluvial plains

**Vegetation:** Cleared




A1: Brownish black or brownish grey (7.5 YR 3/2, 10YR3/1 4/1); loamy sand to sandy clay loam; massive; field pH 6.0 to 6.8. Abrupt change to -

A3: Dark brown or dull yellow orange (10YR3/3, 7.5YR3/3, 10YR6/3); sandy loam to sand clay loam; massive; field pH 6.5 to 7.0. Abrupt change to –

B2: Dull reddish brown or brown (5YR 4/4, 7.5YR4/4, 4/6); sandy medium clay; weak subangular blocky structure; field pH 6.5 to 7.0

# White

**Concept:** Red, strongly structured, non-cracking clay soil developed on basalt on plains

**Australian Classification:** Red Ferrosol

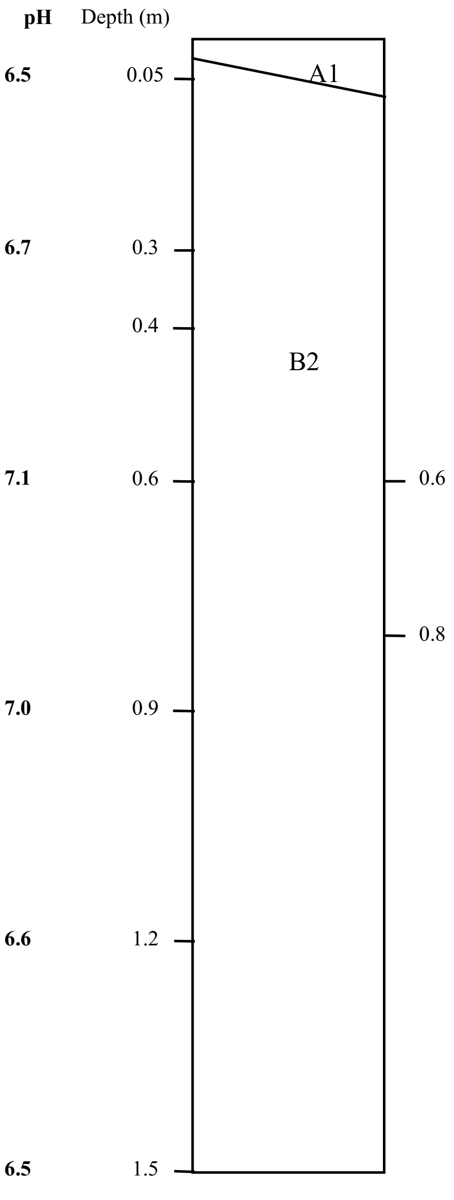
**Great Soil Group:** Euchrozem

**Principle Profile Form:** Uf6.31

**Geology:** Barambah Basalt

**Landform:** Gently undulating plains

**Vegetation:** Cleared, minor open *Eucalyptus* forests




A1: Dark reddish brown (2.5YR3/3, 5YR3/3); light clay to light medium clay; strong granular structure; field pH 6.0 to 6.5. Clear change to -

B2: Reddish brown or dark reddish brown (2.5YR4/6, 3/4, 5YR3/4); light medium to medium clay; strong polyhedral structure; basalt stones are common; field pH 6.0 to 7.0

# Witton

**Concept:** Red, strongly structured non-cracking clay soil developed on basalt on gently undulating rises

**Australian Classification:** Red Ferrosol

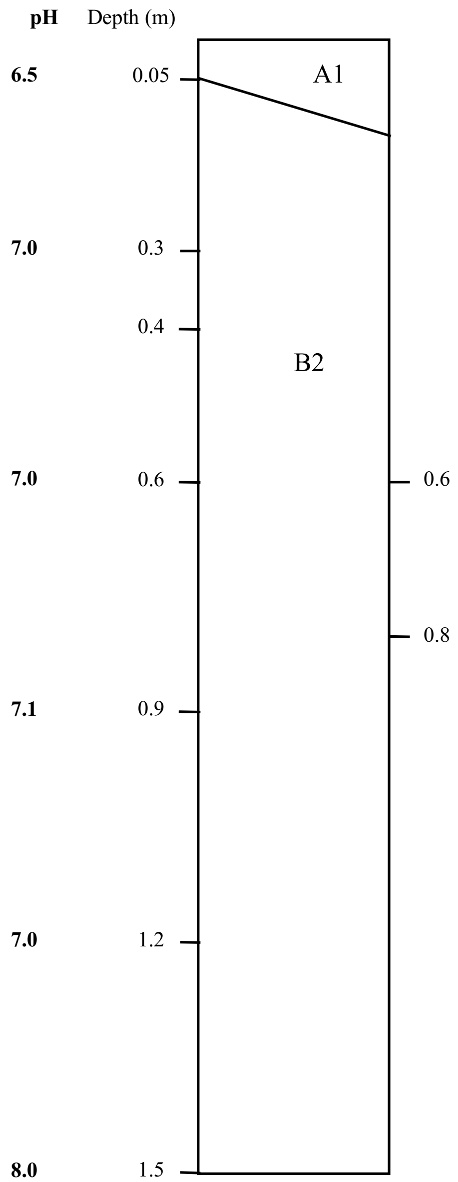
**Great Soil Group:** Euchrozem

**Principle Profile Form:** Uf6.31

**Geology:** Barambah Basalt

**Landform:** Undulating plains and rises

**Vegetation:** Softwood scrub, mostly cleared




A1: Dark reddish brown (2.5YR3/3, 5YR3/2); light clay to light medium clay; strong granular structure; field pH 5.5 to 7.0. Gradational change to -

B2: Dark reddish brown (2.5YR3/4, 4/4); light clay to light medium clay; strong polyhedral structure; basalt stones are common; field pH 6.0 to 7.0

## Witton vertic variant

Same as above except strong lenticular structure in the subsoil.

# Appendix II

## Morphological and analytical data for representative soil profiles

Detailed morphological descriptions and analytical data are provided for 6 representative soil profiles.

**Ferrosols**
White

**Dermosols**
Fletcher
Blair

**Vertosols**
Hind
Dove

**Sodosols**
Fowler

## **Project:** BRCL **Site:** 61 **Observation:** 1 **Soil Name: White**

**Date:** 20011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 388674 mE 7162212 mN ZONE 56 |
| **Landform Element:** | plain |
| **Landform Pattern:** | level plain <9m <1% |
| **Slope:** | 1% |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Uf6.31 |
| **Australian Soil Classification:** | HAPLIC, MESOTROPHIC, RED FERROSOL |
| **Vegetation:** | *Eucalyptus melliodora* |
| **Microrelief Component:** | |
| **Microrelief Description:** | zero or none |
| **Runoff:** | slow |
| **Permeability:** | highly permeable |
| **Drainage:** | well drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | many large pebbles, subangular basalt |
| **Surface Condition:** | firm |

**Profile Morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 to 0.15 m | dark reddish brown (5YR3/3) moist; light clay; strong 2-5mm polyhedral; clear to- |
| B21 | 0.15 to 0.4 m | dark reddish brown (2.5YR3/4) moist; light clay; strong 2-5mm polyhedral; gradual to- |
| B22 | 0.4 to 1.1 m | dark reddish brown (2.5YR3/6) moist; light clay; few large pebbles, subangular basalt; strong 2-5mm polyhedral; diffuse to- |
| B23 | 1.1 to 1.3 m | dark reddish brown (2.5YR3/4) moist; light medium clay; many large pebbles, subangular basalt; weak 2-5mm polyhedral. |

**Field pH**

| Depth (m) | pH |
|---|---|
| 0.05 | 6.5 |
| 0.3 | 6.5 |
| 0.6 | 6 |
| 0.9 | 6 |
| 1.2 | 5.8 |

## **Surface Fertility *White*** (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) Fe | Mn | Cu | Zn |
|---|---|---|---|---|---|---|---|---|---|
| 6.8 | 5.2 | 0.21 | 176 | 1.3 | 4.2 | 41 | 180 | 7.8 | 2.6 |

## **Soil Profile Chemistry Data**

| Depth (cm) | Particle Size (%) @105°C CS | FS | SIL | CLA | pH $H_20$ | EC dS/m | Cl % | Exchangeable Cation CEC | Ca | Mg | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 11 | 12 | 29 | 44 | 7.0 | 0.06 | 0.003 | | | | | |
| 20-30 | 3 | 13 | 25 | 58 | 6.9 | 0.04 | 0.003 | 16 | 4.8 | 1.4 | 0.18 | 0.97 |
| 50-60 | 1 | 7 | 18 | 75 | 6.2 | 0.03 | 0.003 | 11 | 3.5 | 1.0 | 0.15 | 0.48 |
| 80-90 | 1 | 11 | 25 | 62 | 6.2 | 0.06 | 0.006 | 12 | 7.0 | 1.8 | 0.43 | 0.15 |
| 110-120 | 2 | 26 | 29 | 44 | 6.6 | 0.03 | 0.004 | 16 | 4.7 | 2.7 | 0.74 | 0.24 |

| Depth (cm) | Total element P | K | S | Moist WP% @ 105 °C | Disp. Ratio | ESP % |
|---|---|---|---|---|---|---|
| 0-10 | | | | 22 | 0.36 | |
| 20-30 | 0.186 | 0.397 | 0.029 | 22 | 0.26 | 2 |
| 50-60 | 0.152 | 0.271 | 0.017 | 23 | 0.05 | 3 |
| 80-90 | 0.148 | 0.183 | 0.009 | 26 | 0.06 | 5 |
| 110-120 | 0.143 | 0.282 | 0.008 | | | 8.8 |

## **Project:** BRCL **Site:** 4 **Observation:** 1 **Soil Name: Fletcher**

**Date:** 12011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 383877 mE 7156168 mN ZONE 56 |
| **Landform Element:** | plain |
| **Landform Pattern:** | level plain <9m <1% |
| **Slope:** | 0.5% |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Uf6.31 |
| **Australian Soil Classification:** | VERTIC, EUTROPHIC, BROWN DERMOSOL |
| **Vegetation:** | |
| **Microrelief Component:** | |
| **Microrelief Description:** | melonhole gilgai |
| **Runoff:** | very slow |
| **Permeability:** | slowly permeable |
| **Drainage:** | imperfectly drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | |
| **Surface Condition:** | |

**Profile Morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 to 0.06 m | dark brown (7.5YR3/3) moist; light clay; strong <2mm granular; |
| A3 | 0.06 to 0.2 m | brownish black (7.5YR3/2) moist; light clay; strong 2-5mm subangular blocky; |
| B1 | 0.2 to 0.31 m | dull yellowish brown (10YR4/3) moist; light clay; moderate 2-5mm lenticular; very few medium manganiferous nodules; |
| B2 | 0.31 to 0.75 m | brownish black (10YR3/2) moist; light medium clay; few small pebbles, subrounded gravel; moderate 2-5mm lenticular; common medium manganiferous nodules; |

**Field pH**

| Depth (m) | pH |
|---|---|
| 0.05 | 5.5 |
| 0.3 | 5.8 |
| 0.6 | 7 |

**Electrical Conductivity**

| Depth (m) | EC (dS/m) |
|---|---|
| 0.05 | 0.03 |
| 0.3 | 0.04 |
| 0.6 | 0.21 |

**Surface Fertility *Fletcher*** (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fe | Mn | Cu | Zn |
| 6.6 | 2.3 | 0.11 | 9 | 0.3 | 12 | 48 | 39 | 2.5 | 0.32 |

**Soil Profile Chemistry Data**

| Depth | Particle Size (%) @105°C | | | | pH | EC | Cl | Exchangeable Cation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | CS | FS | SIL | CLA | $H_20$ | dS/m | % | CEC | Ca | Mg | Na | K |
| 0-10 | 11 | 12 | 30 | 45 | 5.7 | 0.03 | 0.002 | 21 | 2.0 | 5.5 | 0.59 | 0.27 |
| 20-30 | 5 | 11 | 20 | 63 | 6.3 | 0.03 | 0.002 | 24 | 7.8 | 8.7 | 1.8 | 0.07 |
| 50-60 | 10 | 15 | 27 | 49 | 7.1 | 0.123 | 0.020 | 23 | 2.5 | 9.7 | 3.6 | 0.05 |
| 80-90 | 7 | 13 | 26 | 55 | 8.8 | 0.62 | 0.055 | 24 | 5.4 | 13 | 5.4 | 0.06 |
| 110-120 | | | | | | | | | | | | |

| Depth | Total element | | | Moist WP% @ 105 °C | Disp. | ESP % |
|---|---|---|---|---|---|---|
| (cm) | P | K | S | | Ratio | |
| 0-10 | 0.32 | 0.126 | 0.016 | 19 | 0.38 | 7 |
| 20-30 | 0.031 | 0.119 | 0.015 | 24 | 0.53 | 9.7 |
| 50-60 | 0.028 | 0.150 | 0.014 | 21 | 0.77 | 22.7 |
| 80-90 | 0.028 | 0.149 | 0.015 | 21 | 0.79 | 22.6 |
| 110-120 | | | | | | |

## **Project:** BRCL **Site:** 51 **Observation:** 1 **Soil Name: Blair**

**Date:** 19011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 388019 mE 7168814 mN ZONE 56 |
| **Landform Element:** | plain |
| **Landform Pattern:** | gently undulating plains <9m 1-3% |
| **Slope:** | 2% |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Ug5. |
| **Australian Soil Classification:** | EPISODIC, EPIPEDAL, BROWN VERTOSOL; Non Gravelly, Medium Fine, Medium Fine, Very Deep |
| **Vegetation:** | |
| **Microrelief Component:** | |
| **Microrelief Description:** | zero or none |
| **Runoff:** | slow |
| **Permeability:** | very slowly permeable |
| **Drainage:** | imperfectly drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | no coarse fragments |
| **Surface Condition:** | periodic cracking |

**Profile Morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 to 0.1 m | brownish black (10YR3/2) moist; light medium clay; strong 2-5mm subangular blocky; very few medium manganiferous nodules; clear to- |
| B21 | 0.1 to 0.53 m | dull yellowish brown (10YR5/4) moist; heavy clay; strong 2-5mm lenticular; few medium manganiferous nodules; diffuse to- |
| B22 | 0.53 to 1.6 m | dull yellowish brown (10YR5/4) moist; few fine faint grey mottles; heavy clay; strong 2-5mm lenticular; common medium manganiferous nodules; |

**Field pH**

| Depth (m) | pH |
|---|---|
| 0.05 | 6.8 |
| 0.3 | 8.5 |
| 0.6 | 8.5 |
| 0.9 | 8.3 |
| 1.2 | 8 |
| 1.5 | 8 |

## **Surface Fertility *Blair*** (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fe | Mn | Cu | Zn |
| 6.6 | 1.6 | 0.36 | 223 | 1.8 | 15 | 120 | 100 | 3.5 | 4.8 |

## **Soil Profile Chemistry Data**

| Depth (cm) | Particle Size (%) @105°C | | | | pH | EC | Cl | Exchangeable Cation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CS | FS | SIL | CLA | $H_20$ | dS/m | % | CEC | Ca | Mg | Na | K |
| 0-10 | | | | | 6.8 | 0.12 | 0.005 | | | | | |
| 20-30 | 9 | 18 | 19 | 57 | 8.4 | 0.12 | 0.006 | 38 | 17 | 15 | 2.1 | 0.35 |
| 50-60 | 9 | 19 | 19 | 57 | 8.5 | 0.68 | 0.090 | 37 | 13 | 19 | 5.8 | 0.14 |
| 80-90 | 11 | 18 | 19 | 56 | 8.0 | 1.6 | 0.228 | 38 | 10 | 19 | 8.7 | 0.14 |
| 110-120 | 8 | 18 | 20 | 58 | 7.7 | 1.7 | 0.252 | 38 | 9.4 | 22 | 9.4 | 0.14 |
| 140-150 | | | | | 7.6 | 1.7 | 0.259 | | | | | |

| Depth (cm) | Total element | | | Moist WP% @ 105 °C | Disp. Ratio | ESP % |
|---|---|---|---|---|---|---|
| | P | K | S | | | |
| 0-10 | 0.171 | 0.477 | 0.055 | 24 | | |
| 20-30 | 0.063 | 0.257 | 0.019 | 25 | 0.63 | 6 |
| 50-60 | 0.053 | 0.227 | 0.019 | 25 | 0.83 | 15.3 |
| 80-90 | 0.059 | 0.223 | 0.024 | 24 | 0.87 | 23 |
| 110-120 | 0.059 | 0.225 | 0.019 | | | 23 |
| 140-150 | | | | | | |

## Project: BRCL Site: 16 Observation: 1 Soil Name: Hind

**Date:** 13011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 382146 mE 7159693 mN ZONE 56 |
| **Landform Element:** | plain |
| **Landform Pattern:** | level plain <9m <1% |
| **Slope:** | 1 % |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Ug5.16 |
| **Australian Soil Classification:** | EPISODIC-EPICALCAREOUS, SELF-MULCHING, BLACK VERTOSOL; Non Gravelly, Medium Fine, Medium Fine, Very Deep |
| **Vegetation:** | |
| **Microrelief Component:** | |
| **Microrelief Description:** | zero or none |
| **Runoff:** | slow |
| **Permeability:** | slowly permeable |
| **Drainage:** | imperfectly drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | common large pebbles, subangular Basalt |
| **Surface Condition:** | periodic cracking, self-mulching |

**Profile Morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 to 0.03 m | brownish black (10YR3/1) moist; heavy clay; strong 2-5mm granular; very few medium calcareous nodules; clear to- |
| B21 | 0.03 to 0.15 m | brownish black (10YR3/1) moist; medium heavy clay; strong 2-5mm subangular blocky; very few medium calcareous nodules; gradual to- |
| B22 | 0.15 to 0.6 m | brownish black (10YR3/1) moist; medium clay; strong 2-5mm lenticular; few medium calcareous nodules; gradual to- |
| B23 | 0.6 to 0.79 m | brownish grey (10YR4/1) moist; light medium clay; strong 2-5mm lenticular; common medium calcareous nodules; gradual to- |
| B24 | 0.79 to 1.05 m | dark greyish yellow (2.5Y5/2) moist; light medium clay; strong 2-5mm lenticular; few coarse calcareous nodules; gradual to- |
| B25 | 1.05 to 1.45 m | dark greyish yellow (2.5Y5/2) moist; light medium clay; strong 2-5mm lenticular; very few medium calcareous nodules, very few fine manganiferous nodules; |

**Field pH**

| Depth (m) | pH |
|---|---|
| 0.05 | 9.5 |
| 0.3 | 9.5 |
| 0.6 | 9 |
| 0.9 | 9 |
| 1.2 | 9 |

## Surface Fertility *Hind* (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fe | Mn | Cu | Zn |
| 8.8 | 3.7 | 0.12 | 11 | 0.70 | 15 | 4.6 | 18 | 3.6 | 0.32 |

## Soil Profile Chemistry Data

| Depth (cm) | Particle Size (%) @105$^{o}$C | | | | pH | EC | Cl | Exchangeable Cation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CS | FS | SIL | CLA | $H_20$ | dS/m | % | CEC | Ca | Mg | Na | K |
| 0-10 | | | | | 9.1 | 0.24 | 0.005 | 56 | 20 | 25 | 4.7 | 0.37 |
| 20-30 | 5 | 11 | 17 | 67 | 9.0 | 0.84 | 0.060 | 58 | 15 | 28 | 11 | 0.23 |
| 50-60 | 9 | 10 | 17 | 67 | 8.8 | 1.6 | 0.129 | 53 | 9.9 | 32 | 13 | 0.13 |
| 80-90 | 17 | 12 | 13 | 59 | 9.1 | 1.0 | 0.085 | 44 | 8.4 | 25 | 10 | 0.14 |
| 110-120 | | | | | | | | | | | | |

| Depth (cm) | Total element | | | Moist WP% @ 105 $^{0}$C | Disp. Ratio | ESP % |
|---|---|---|---|---|---|---|
| | P | K | S | | | |
| 0-10 | 0.025 | 0.482 | 0.032 | 35 | 0.83 | 9 |
| 20-30 | 0.022 | 0.420 | 0.042 | 39 | 0.89 | 20 |
| 50-60 | 0.017 | 0.364 | 0.089 | 35 | 0.79 | 24 |
| 80-90 | 0.028 | 0.394 | 0.055 | 32 | 0.40 | 23 |
| 110-120 | | | | | | |

# **Project:** BRCL **Site:** 9 **Observation:** 1 **Soil Name: Dove**

**Date:** 12011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 382719 mE 7157092 mN ZONE 56 |
| **Landform Element:** | drainage depression |
| **Landform Pattern:** | level plain <9m <1% |
| **Slope:** | 0 % |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Ug5.24 |
| **Australian Soil Classification:** | EPISODIC-ENDOCALCAREOUS, SELF-MULCHING, GREY VERTOSOL; Non Gravelly, Medium Fine, Medium Fine, Very Deep |
| **Vegetation:** | |
| **Microrelief Component:** | |
| **Microrelief Description:** | zero or none |
| **Runoff:** | very slow |
| **Permeability:** | very slowly permeable |
| **Drainage:** | very poorly drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | no coarse fragments |
| **Surface Condition:** | periodic cracking, self-mulching |

**Profile Morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 to 0.04 m | brownish black (10YR3/1) moist; medium heavy clay; strong <2mm granular; gradual to- |
| B21 | 0.04 to 0.25 m | brownish grey (7.5YR4/1) moist; heavy clay; strong 2-5mm subangular blocky; gradual to- |
| B22 | 0.25 to 0.55 m | brownish grey (7.5YR4/1) moist; heavy clay; strong 2-5mm lenticular; gradual to- |
| B23 | 0.55 to 0.9 m | brownish grey (7.5YR4/1) moist; medium clay; strong 2-5mm lenticular; very few medium calcareous nodules; gradual to- |
| B24 | 0.9 to 1.4 m | brownish grey (10YR5/1) moist; medium clay; strong 2-5mm lenticular; few medium calcareous nodules; |

**Field pH**

| Depth (m) | pH |
|---|---|
| 0.05 | 7 |
| 0.3 | 9 |
| 0.6 | 9.5 |
| 0.9 | 9.5 |
| 1.2 | 9.5 |
| 1.5 | 9.5 |

**Electrical Conductivity**

| Depth (m) | EC (dS/m) |
|---|---|
| 0.05 | 0.04 |
| 0.3 | 0.18 |
| 0.6 | 0.85 |
| 0.9 | 1.48 |
| 1.2 | 1.48 |

## Surface Fertility *Dove* (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Fe | Mn | Cu | Zn |
| 7.4 | 1.8 | 0.15 | 9 | 0.9 | 10 | 48 | 51 | 2.6 | 0.59 |

## Soil Profile Chemistry Data

| Depth | Particle Size (%) @105°C | | | | pH | EC | Cl | Exchangeable Cation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | CS | FS | SIL | CLA | $H_20$ | dS/m | % | CEC | Ca | Mg | Na | K |
| 0-10 | 6 | 3 | 9 | 79 | 7.3 | 0.12 | 0.004 | 59 | 18 | 33 | 2.4 | 0.51 |
| 20-30 | 3 | 4 | 11 | 80 | 8.6 | 0.17 | 0.013 | 57 | 18 | 36 | 5.3 | 0.27 |
| 50-60 | 2 | 8 | 9 | 83 | 8.6 | 0.99 | 0.066 | 56 | 11 | 38 | 10 | 0.29 |
| 80-90 | 10 | 12 | 12 | 67 | 9.0 | 1.5 | 0.163 | 47 | 7.9 | 32 | 10 | 0.27 |
| 110-120 | 11 | 12 | 12 | 62 | 9.1 | 1.4 | 0.163 | 46 | 6.8 | 35 | 11 | 0.29 |
| 140-150 | | | | | 9.1 | 1.2 | 0.123 | | | | | |

| Depth | Total element | | | Moist WP% @ 105 °C | Disp. | ESP % |
|---|---|---|---|---|---|---|
| (cm) | P | K | S | | Ratio | |
| 0-10 | 0.028 | 0.648 | 0.037 | 38 | 0.74 | |
| 20-30 | 0.016 | 0.629 | 0.021 | 38 | 0.81 | |
| 50-60 | 0.011 | 0.636 | 0.028 | 35 | 0.88 | |
| 80-90 | 0.009 | 0.586 | 0.046 | 29 | 0.86 | |
| 110-120 | 0.008 | 0.572 | 0.050 | | | |

# **Project:** BRCL **Site:** 2 **Observation:** 1 **Soil Name: Fowler**

**Date:** 12011999 **Described By:** McCarroll, S (Sue)

| | |
|---|---|
| **Location:** | 384487 mE 7156421 mN ZONE 56 |
| **Landform Element:** | plain |
| **Landform Pattern:** | level plain <9m <1% |
| **Slope:** | 0.5 % |
| **Great Soil Group:** | |
| **Principal Profile Form:** | Db3.33 |
| **Australian Soil Classification:** | VERTIC, SUBNATRIC, BROWN SODOSOL |
| **Vegetation:** | *Eucalyptus melanophloia* |
| **Microrelief Component:** | |
| **Microrelief Description:** | zero or none |
| **Runoff:** | slow |
| **Permeability:** | moderately permeable |
| **Drainage:** | imperfectly drained |
| **Substrate Lithology:** | |
| **Surface Coarse Fragments:** | common large pebbles, subangular basalt |
| **Surface Condition:** | firm |

**Profile Morphology:**

| **Horizon** | **Depth** | **Description** |
|---|---|---|
| A11 | 0 to 0.1 m | brownish black (7.5YR3/2) moist; clay loam; sandy; very few small pebbles, subrounded gravel; moderate 2-5mm granular; very few fine manganiferous nodules; clear to- |
| A12 | 0.1 to 0.27 m | brown (7.5YR4/3) moist; sandy clay loam; very few small pebbles, subrounded gravel; weak 2-5mm granular; very few fine manganiferous nodules; abrupt to- |
| A2j | 0.27 to 0.3 m | dull brown (7.5YR5/3) moist; sandy clay loam; very few small pebbles, subrounded gravel; very few fine manganiferous nodules; abrupt to- |
| B21 | 0.3 to 0.52 m | brown (10YR4/4) moist; light medium clay; very few small pebbles, subrounded gravel; strong <2mm lenticular; very few fine manganiferous soft segregations, very few fine manganiferous nodules; gradual to- |
| B22 | 0.52 to 0.9 m | dull yellowish brown (10YR5/4) moist; medium clay; strong 2-5mm lenticular; very few fine manganiferous soft segregations; gradual to- |
| B23 | 0.9 to 0.94 m | yellowish brown (2.5Y 5/4) moist; medium clay; few medium pebbles, subangular basalt; strong 2-5mm lenticular; |

**Field pH**

| **Depth (m)** | **pH** |
|---|---|
| 0.05 | 5.8 |
| 0.3 | 6 |
| 0.6 | 9 |
| 0.9 | 9 |

**Electrical Conductivity**

| **Depth (m)** | **EC (dS/m)** |
|---|---|
| 0.05 | 0.03 |
| 0.3 | 0.03 |
| 0.6 | 0.39 |
| 0.9 | 0.68 |

## **Surface Fertility *Fowler*** (Bulked Sample, 0-10cm)

| pH | Org. C % | Total N % | C/N Ratio | Avail P (mg/kg) | Avail K Meq % | SO4-S (mg/kg) | DTPA Extractable trace elements (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fe | Mn | Cu | Zn |
| 6.1 | 1.6 | 0.11 | 8 | 11 | 0.20 | 8.3 | 69 | 73 | 2.6 | 0.79 |

## **Soil Profile Chemistry Data**

| Depth (cm) | Particle Size (%) @105°C | | | | pH $H_20$ | EC dS/m | Cl % | Exchangeable Cation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CS | FS | SIL | CLA | | | | CEC | Ca | Mg | Na | K |
| 0-10 | 27 | 24 | 24 | 26 | 5.9 | 0.03 | 0.001 | 16 | 1.9 | 3.7 | 0.16 | 0.23 |
| 18-28 | 25 | 29 | 27 | 23 | 6.4 | 0.02 | 0.001 | 12 | 1.9 | 2.7 | 0.56 | 0.05 |
| 28-38 | 17 | 19 | 17 | 48 | 6.8 | 0.04 | 0.003 | 15 | 5.7 | 6.4 | 1.6 | 0.07 |
| 50-60 | 12 | 10 | 10 | 69 | 8.2 | 0.20 | 0.023 | 21 | 4.2 | 10 | 3.7 | 0.07 |
| 80-90 | 9 | 14 | 14 | 66 | 8.6 | 0.44 | 0.051 | 24 | 5.1 | 15 | 5.6 | 0.08 |

| Depth (cm) | Total element | | | Moist WP% @ 105 °C | Disp. Ratio | ESP % |
|---|---|---|---|---|---|---|
| | P | K | S | | | |
| 0-10 | 0.073 | 0.267 | 0.032 | 21 | 0.47 | 3 |
| 18-28 | 0.043 | 0.245 | 0.013 | 22 | 0.63 | 10.7 |
| 28-38 | 0.035 | 0.205 | 0.014 | 23 | 0.63 | 14 |
| 50-60 | 0.023 | 0.219 | 0.013 | 24 | 0.87 | 21 |
| 80-90 | 0.019 | 0.256 | 0.010 | - | 0.93 | 22 |

# Appendix III

## Land Suitability Classes

Class definition

Five land suitability classes have been defined for use in Queensland, with land suitability decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a specified land use, which allows optimum production with minimal degradation to the land resource in the long term.

| | |
|---|---|
| Class 1 | Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production. |
| Class 2 | Suitable land with minor limitations which either reduce production or require more than the simple management practices of class 1 land to maintain economic production. |
| Class 3 | Suitable land with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production. |
| Class 4 | Marginal land which is presently considered unsuitable due to severe limitations. The long term or precise effects of these limitations on the proposed land use are unknown. The use of this land is dependent upon either undertaking additional studies to determine its suitability for sustained production or reducing the effects of the limitation(s) to achieve production. |
| Class 5 | Unsuitable land with extreme limitations that preclude its use. |

Land is considered less suitable as the severity of limitations for a land use increase, reflecting either (a) reduced potential for production, and/or (b) increased inputs to achieve an acceptable level of production and/or (c) increased inputs required to prevent land degradation. The first three classes are considered suitable for the specified land use as the benefits from using the land for that land use in the long term should outweigh the inputs required to initiate and maintain production. Decreasing land suitability within a region often reflects the need for increased inputs rather than decreased potential production. Class 4 is considered presently unsuitable and is used for marginal land where it is doubtful that the inputs required to achieve and maintain production outweigh the benefits in the long term. It is also used for land where reducing the effect of a limitation may allow it to be upgraded to a higher suitability class, but additional studies are needed to determine the feasibility of this.

Class 5 is considered unsuitable having limitations that in aggregate are so severe that the benefits would not justify the inputs required to initiate and maintain production in the long term. It would require a major change in economics, technology or management expertise before the land could be considered suitable for that land use. Some class 5 lands however, such as escarpments, will always remain unsuitable for agriculture.

# Land Suitability Classification Scheme for Irrigated Crops

The classification scheme is a summary of each limitation describing the effects of the limitation on plant growth, machinery use and land degradation, and how the soil/land attributes are assessed, and how the limitation classes are determined. The classes are defined in Appendix III. The codes listed in this appendix for each limitation are the soil/land attribute level recorded in the UMA file.

Irrigation method is assumed to be spray (travelling irrigators or other overhead spray method) unless otherwise stated. Furrow irrigation is a separate land use. Pastures are not listed under the wetness and flooding limitations where species selection enables adaption to a wide range of conditions.

The agricultural land uses listed are:

Asparagus*
Avocado
Beans
Chickpeas*
Citrus
Cotton*
Crucifers* (cabbage, cauliflowers, etc)
Cucurbits
Furrow irrigation (other than sugar cane)
Grape*
Improved pasture
Lychee
Lucerne
Macadamia
Maize
Mango
Mungbean*
Navybean
Peanut
Pecan*
Pineapple
Vegetables (capsicum, tomato, zucchini)
Potato
Safflower*
Sorghum
Soybean
Stonefruit (peaches, nectarines)
Summer grain**
Sunflower*
Sugar cane (spray irrigation)
Sugar cane (furrow irrigation)
Sweet corn
Sweet potato

## CLIMATE (c)

**Effect**

Frosts may suppress growth, kill plants and reduce yield.

**Assessment**

The incidence and severity of frosts are used to distinguish affected areas.

**Limitation class determination**

Crop tolerance and local experience of the incidence and severity of frosts. For example, severe frosts cause severe damage to sugar cane stalk tissue, which reduces sugar content unless it is harvested within two weeks, depending on weather conditions.

| Soil/land attribute level | Limitation classes for various crops | | | |
|---|---|---|---|---|
| | Avocado, Macadamia, Mango | Citrus, Vegetables, Cucurbits, Pineapple, Sweet Potato, Beans, Sweet Corn, Lychee | Sugar Cane | All other crops * |
| Frost free to light frosts (hill tops or near coastal areas ) Code: C1 | 2 | 1 | 1 | 1 |
| Regular frosts Code: C2 | 5 | 3 | 2 | 1 |
| Severe frosts (channel benches, depressions in lower terraces ) Code: C3 | 5 | 4 | 3 | 1 |

* All other crops refer to crops listed in this appendix. Seasonal adaptation is not considered, for example, summer crops are not grown in winter.

## WATER AVAILABILITY (m)

**Effect**

Plant yield will be decreased by periods of water stress particularly during critical growth periods.

**Assessment**

Plant available water capacity (PAWC) is used as a measure of the amount of water in a soil available to plants over the rooting depth.

PAWC is based on predicted values (Littleboy 1997, Shaw and Yule 1978†). Generally, soil texture, structure and clay mineralogy over the effective rooting depth[1] are important attributes affecting PAWC.

**Limitation class determination**

PAWC classes relate to the frequency of irrigation for spray or furrow irrigation only:

>100 mm = 15 days
75 to 100 mm = 12 to 15 days
50 to 75 mm = 8 to 12 days
<50 mm = <8 days

Irrigation frequency considers crop rooting depth, seasonal evaporation rates (6 mm/day in summer) and the amount of labour and equipment required. For example, shallow rooted crops require more frequent irrigation compared to deep rooted crops, while winter crops require less frequent irrigation compared to summer crops. More frequent irrigation requires a greater amount of labour and/or more equipment. Negligible limitations apply to microsprinkler or drip irrigation systems where small amounts of water are added frequently.

| Soil/land attribute level | Limitation class for various crops | | | |
|---|---|---|---|---|
| | Microsprinkler/drip irrigation - Avocado, Citrus, Macadamia, Mango, Lychee, Stone fruit, Grapes, Veges, Cruciferae, Pecan | Cucurbits, Asparagus, Potato, Navybean, Beans, Sweet corn, Sweet potato | Peanuts, Lucerne, Maize, Sorghum, Soybean, Pastures, Pineapples, Chickpeas, Mungbeans, Safflower, Sunflower, Summer grains, Winter grains, Cotton | Sugar cane |
| Soil PAWC (to 1.0 m) | | | | |
| >150 mm Code M1 | 1 | 2 | 1 | 1 |
| 150-125 mm Code: M2 | 1 | 2 | 1 | 1 |
| 125-100 mm Code: M3 | 1 | 2 | 1 | 1 |
| 75-100 mm Code: M4 | 1 | 2 | 1 | 2 |
| 50-75 mm Code: M5 | 1 | 2 | 2 | 3 |
| <50 mm Code: M6 | 1 | 3 | 3-4 | 4 |

[1] Effective rooting depth is taken to the depth of optimal water extraction by roots. For example, tree crops 1-1.5 m, small crops 0.5 m, field crops, sugar cane and grapes 1.0 m; or to the depth of high salt concentration, rock or impermeable layers.

† Littleboy M (1997). *Spatial generalisation of biophysical simulation models for quantitative land evaluation: a case study for dryland wheat growing areas of Queensland*. Doctor of Philosophy Thesis, University of Queensland.

Shaw R and Yule D (1978). *The assessment of soils for irrigation, Emerald, Queensland*. Queensland Department of Primary Industries, Agricultural Chemistry Branch, Technical Report 13.

## WETNESS (w)

**Effect**
Waterlogged soils will reduce plant growth and delay effective machinery operations.

**Assessment**
Internal and external drainage are assessed. Indicator attributes of internal drainage include texture, grade and type of structure, colour, mottles, segregations and impermeable layers. Drainage class[1] and soil permeability[2] (McDonald *et al.* 1990†) are assessed in relation to plant rooting depth. Slope and topographic position determine external drainage.

**Limitation class determination**
Consultation, crop tolerance information and the effects of delays in machinery operations.

[1] Drainage class: This accounts for all aspects of internal and external drainage in the existing state.

Drainage class
1 Very poorly drained
2 Poorly drained
3 Imperfectly drained
4 Moderately well drained
5 Well drained
6 Rapidly drained

[2] Permeability
H Highly permeable (Ks >500 mm/day)
M Moderately permeable (Ks 50–500 mm/day)
S Slowly permeable (Ks 5–50 mm/day)
V Very slowly permeable (Ks <5 mm/day)

| **Soil/land attribute level** | **Limitation classes for various crops** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **(a) Depth req. 0 to 1.5 m (Code: W3)** | | | | **(b) Depth req. 0 to 1 m Code (W1))** | | **(c) Depth req. 0 to 0.5 m (Code: W2** | | |
| | Avocado | Citrus Macadamia Pecan | Mango | Lychees | Lucerne Stone- fruit, Grape Safflower Mungbean Chickpea | Maize, Sorghum (forage), Sweet corn, Soybean Summer grain Winter grain Sunflower Cotton | Sugar cane | Navybean Peanuts, Beans | Veges, Cruciferae, Cucurbits, Asparagus, Potato, Pineapple, Sweet potato |
| 6H | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5H | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5M | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 |
| 4H | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 |
| 4M | 4 | 3 | 2 | 1 | 3 | 2 | 1 | 3 | 2 |
| 4S | 5 | 4 | 3 | 2 | 4 | 3 | 2 | 4 | 3 |
| 4V | 5 | 4 | 3 | 2 | 4 | 3 | 2 | 4 | 3 |
| 3H | 4 | 3 | 2 | 2 | 3 | 2 | 2 | 3 | 2 |
| 3M | 5 | 4 | 3 | 2 | 4 | 3 | 2 | 4 | 3 |
| 3S | 5 | 5 | 4 | 3 | 5 | 4 | 3 | 5 | 4 |
| 3V | 5 | 5 | 4 | 3 | 5 | 4 | 3 | 5 | 4 |
| 2H | 5 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 5 |
| 2M | 5 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 5 |
| 2S | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 |
| 2V | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 |
| 1H | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| 1M | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| 1S | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 1V | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

† McDonald RC, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne.

## SOIL DEPTH (d)

**Effect**

Shallow soils limit root proliferation and anchorage.  Plants may be uprooted during strong winds.

**Assessment**

Effective soil rooting depth:  Depth to decomposing rock,  pan, high salts  or impermeable layer.

**Limitation class determination**

Consultation.

| Soil/land attribute level | Limitation classes for various crops | | |
|---|---|---|---|
| Effective soil depth | Tree crops | Sugar cane | All other crops |
| > 1 m Code:  D1 | 1 | 1 | 1 |
| 0.6 to 1 m Code:  D2 | 2 | 1 | 1 |
| 0.4 to 0.6 m Code:  D3 | 3 | 1 | 1 |
| 0.3 to 0.4 m Code:  D4 | 4 | 2 | 1 |
| < 0.3 m Code:  D5 | 5 | 5 | 5 |

## ROCKINESS (r)

**Effect**

Coarse (rock) fragments[1] and rock in the plough zone interfere with the efficient use of, and can damage agricultural machinery. Surface rock in particular interferes with the harvesting machinery of sugar cane, soybean, root crops and some vegetables.

**Assessment**

Based on the size, abundance (McDonald *et al.* 1990†) and distribution of coarse fragments in the plough layer, as well as machinery and farmer tolerance of increasing size and content of coarse fragments.

**Limitation class determination**

Consultation, particularly related to farmer tolerances which are implicitly related to profitability and technological capability.

| Soil/land attribute level | | Limitation classes for various crops | | | | |
|---|---|---|---|---|---|---|
| Size | Amount (%) | Avocado, Macadamias, Citrus, Mango, Lychee, Stone fruit, Grapes, Pastures, Pecan | Pineapple | Sugar cane, Maize, Sorghum, Sweet corn, Safflower, Sunflower, Summer crops | Soybean, Veges, Cucurbits, Lucerne, Cruciferae, Asparagus, Beans, Mungbeans, Winter grains, Cotton | Peanut, Sweet potato, Potato, Navybean Chickpea |
| No coarse fragments | | 1 | 1 | 1 | 1 | 1 |
| Code: RO | | | | | | |
| 6–20 mm | <2 | 1 | 1 | 1 | 1 | 2 |
| (Pebbles) | 2–10 | 1 | 1 | 1 | 2 | 3 |
| Codes: P1-5 | 10–20 | 1 | 1 | 2 | 3 | 4 |
| | 20–50 | 1 | 2 | 3 | 4 | 5 |
| | >50 | 2 | 3 | 4 | 5 | 5 |
| 20–60 mm | <2 | 1 | 1 | 1 | 2 | 5 |
| (Gravel) | 2–10 | 1 | 1 | 2 | 3 | 4 |
| Codes: G1-5 | 10–20 | 1 | 2 | 3 | 4 | 5 |
| | 20–50 | 2 | 3 | 4 | 5 | 5 |
| | >50 | 3 | 4 | 5 | 5 | 3 |
| 60 - 200 mm | <2 | 1 | 1 | 2 | 3 | 4 |
| (Cobble) | 2–10 | 1 | 2 | 3 | 4 | 5 |
| Codes: C1-5 | 10–20 | 2 | 3 | 4 | 5 | 5 |
| | 20–50 | 3 | 4 | 5 | 5 | 5 |
| | >50 | 4 | 5 | 5 | 5 | 5 |
| 20– 600 mm | <2 | 1 | 2 | 3 | 4 | 5 |
| (Stone) | 2–10 | 2 | 3 | 4 | 5 | 5 |
| Codes: S1-5 | 10–20 | 3 | 4 | 5 | 5 | 5 |
| | 20–50 | 4 | 5 | 5 | 5 | 5 |
| | >50 | 5 | 5 | 5 | 5 | 5 |
| >600 mm | <2 | 2 | 3 | 4 | 5 | 5 |
| (Boulders or rock) | 2–10 | 3 | 4 | 5 | 5 | 5 |
| Codes: B1-5 | 10–20 | 4 | 5 | 5 | 5 | 5 |
| R1-5 | 20–50 | 5 | 5 | 5 | 5 | 5 |
| | >50 | 5 | 5 | 5 | 5 | 5 |

[1] Coarse fragments are particles greater than 2 mm and not continuous with underlying bedrock (McDonald *et al.* 1990†). Rock is defined as being continuous with bedrock.

† McDonald RC, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne.

## MICRORELIEF (tm)

**Effect**

Uneven and lower crop productivity due to uneven water distribution, for example, water ponding in depressions.

**Assessment**

Levelling of uneven surface is required for efficient irrigation and surface drainage. The vertical interval of gilgai, channel and other microrelief dictates the amount of levelling required.

**Limitation class determination**

Local opinion and consultation.

| Soil/land attribute level | Limitation classes for various crops |
|---|---|
| Vertical interval | All crops |
| <0.1m Code: MO | 1 |
| 0.1 to 0.3 m Code: M1 | 3 |
| 0.3 to 0.6 m Code: M2 | 4 |
| >0.6 m Code: M3 | 5 |

## FLOODING (f)

**Effect**

Yield reduction or plant death caused by anaerobic conditions and/or high water temperature and/or silt deposition during inundation, as well as physical removal or damage by flowing water. Flowing water can cause erosion.

**Assessment**

Assessing the effects of flooding on an individual UMA is difficult. Flooding frequency has been used to distinguish between suitable and unsuitable land only in extreme frequency situations or for intolerant crops. Where flood frequency is significant but not extreme, a '0' (zero) has been used to indicate the occurrence of flooding, but due to insufficient knowledge[1], it is not used to downgrade this suitability class.

**Limitation class determination**

Consultation.

| Soil/land attribute level | Limitation classes for various crops | | | |
|---|---|---|---|---|
| | Sugar cane, Soybean, Maize, Sorghum, Asparagus, Sweet corn Cotton, Safflower, Sunflower, Winter grains, Summer grain | Avocado, Macadamias, Citrus, Pineapple, Mango, Lychee, Stone fruits, Grapes, Pecan | Lucerne, Navybean, Beans, Peanuts Chickpeas, Mungbeans | Veges, Cucurbits, Potato, Sweet potato, Cruciferae |
| No flooding or flooding less than 1 in 10 years.<br>Code: FO, F1 | 1 | 1 | 1 | 1 |
| Flooding frequency of approximately 1 in 2 to 1 in 10 years - levees and back swamps and some higher channel benches.<br>Code: F2 | 0 | 5 | 0 | 1 |
| Flooding frequency approaches annual occurrence - lower channel benches.<br>Code: F3 | 4 | 5 | 5 | 1 |

[1] Sugar cane is commonly grown on these lands despite regular flooding. The real effects of flooding do not detract from the value of the land.

## TOPOGRAPHY (ts)

**Effect**

The safety and/or efficiency of farm vehicle operation is affected by:

- land slopes in relation to roll stability and side slip.
- erosion control layouts with short rows and sharp curves in row crops on land with variability in degree and direction of slope (complex slopes).

**Assessment**

- Steepness of slope in relation to safety and efficiency.
- Variation in slope causing short rows in erosion control layouts.
- Variation in slope direction causing excessive row curvature in erosion control layouts.

**Limitation class determination**

- Local experience and consultation regarding the upper machinery slope limit for various land uses.
- Farmer tolerance of short rows.
- Inability of trailing implements to effectively negotiate curves with less than 30 m radius.

| Soil/land attribute level | Limitation classes for various crops | | |
|---|---|---|---|
| Slope (%) | Avocado, Citrus, Stone fruits, Mango, Lychee, Macadamias, Grapes, Pecan | Sugar cane, Maize, Veges, Sorghum, Soybean, Peanut, Cucurbits, Sweet corn, Sweet potato, Pineapple, Navybean, Lucerne, Cruciferae, Asparagus, Potato, Beans, Summer grain, Winter grain, Cotton, Safflower, Sunflower, Chickpeas, Mungbeans | Pastures |
| 0–15% Code: S0 | 1 | 1 | 1 |
| 15–20% Code: S1 | 2 | 4 | 1 |
| 20–30% Code: S2 | 4 | 5 | 2 |
| >30% Code: S3 | 5 | 5 | 5 |
| Complex slopes 0–15% Code: C | 1 | 0[1] | 1 |

[1] Complex slopes are not downgraded. A ‘0’ (zero) is used to flag that minimum tillage and modified erosion control structures have to be applied in lieu of conventional erosional control structures.

## SOIL PHYSICAL CONDITION (p)

**Effect**

- Germination and seedling development problems are associated with adverse conditions of the surface soil such as hardsetting, coarse aggregates, and crusting clays (ps)[1].
- Soils with a narrow moisture range for cultivation can create difficulties in achieving favourable tilth (pm)[1].
- Soil adhesiveness can cause harvest difficulties and affect the quality of subsurface harvest material (pa)[1].

**Assessment**

- Soils with indicative morphological properties are evaluated in the context of local experience or knowledge of plant characteristics, for example, seed size, tuberous roots.
- Local experience indicates problems associated with certain soils, for example, narrow moisture range for cultivation.

**Limitation class determination**

- Plant tolerance limits and requirements in relation to germination and harvesting are matched with soil properties and supported by local experience.
- Local opinion of the severity of the problem of narrow moisture range.

| Soil/land attribute level | Limitation classes for various crops | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peanut | Navybean, Lucerne, Mungbeans, Chickpeas, Sunflower, Safflower | Veges, Cruciferae, Cucurbits, Maize, Sorghum, Sweet corn, Pineapple, Asparagus, Beans, Cotton, Summer grain, Winter grain | Potato, Sweet potato | Sugar cane | Soybean | Avocado, Macadamias, Citrus, Stone fruits, Mango, Lychee, Grapes, Pecan | Pastures |
| No restrictions<br>Code: S0, M0, A0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Hardsetting massive soils with sandy loam to clay loam surface textures with dry moderately firm consistency<br>Code: S1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Hardsetting massive soils with fine sandy loam to clay loam fine sandy surface textures with dry very firm consistency<br>Code: S2 | 3 | 3 | 2 | 3 | 2 | 3 | 1 | 3 |
| Crusting clays<br>Code: S3 | 2 | 2 | 2 | 2 | 1 | 3 | 1 | 2 |
| Large Aggregate size >20 mm<br>Code: S4 | 4 | 4 | 3 | 2 | 2 | 4 | 1 | 3 |
| Moderate moisture range<br>Code: M1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| Narrow moisture range<br>Code: M2 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 2 |
| Slightly adhesive soils<br>Code: A1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Moderately adhesive soils<br>Code: A2 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| Strongly adhesive soils<br>Code: A3 | 4 | 1 | 1 | 3 | 1 | 1 | 1 | 1 |

[1] (ps, pm and pa) are abbreviated to Codes (S, M and A) respectively.

## SECONDARY SALINISATION (s)

**Effect**
Drainage losses from permeable soils, usually higher in the landscape, may cause secondary salinisation downslope.

**Assessment**
Soil permeability (McDonald *et al* 1990†) and position in the landscape are used to determine intake areas, and the effect that deep drainage may have on watertables downslope. High watertable may occur above areas where heavy textured slowly permeable soils occur. Drainage class, permeability (see wetness) and position in landscape determine the likelihood of salinisation.

**Limitation class determination**
Drainage class, soil permeability and position in the landscape. Soil hydraulic conductivity, groundwater level and salinity measurements are required for a wide range of soils and landscapes. Any UMA with existing salinity is class 5.

| Land/soil attribute level | Limitation classes for all crops | | | |
|---|---|---|---|---|
| Soil drainage/permeability at 1 m (see wetness limitation) | Landscape position | | | |
| | Upper slopes (U) | Lower slope (L) | Drainage depressions +(D) | Level plains |
| | All crops | All crops | All crops | All crops |
| 6H | 0 * | 0 | - | 1 |
| 5H | 0 | 0 | - | 1 |
| 5M | 0 | 0 | - | 1 |
| 4H | 0 | 2 | - | 1 |
| 4M | 0 | 2 | - | 1 |
| 4S | 0 | 3 | - | 2 |
| 4V | 0 | 3 | - | 2 |
| 3H | 0 | 2 | 5 | 1 |
| 3M | 0 | 3 | 5 | 2 |
| 3S | 0 | 4 | 5 | 3 |
| 3V | 0 | 5 | 5 | 3 |
| 2H | 0 | 3 | 5 | 2 |
| 2M | 0 | 4 | 5 | 3 |
| 2S | 0 | 5 | 5 | 4 |
| 2V | 0 | 5 | 5 | 4 |
| 1H | - | 4 | 5 | 3 |
| 1M | - | 4 | 5 | 3 |
| 1S | - | 4 | 5 | 3 |
| 1V | - | 4 | 5 | 3 |
| existing salinisation | 5 | 5 | 5 | 5 |

* 0 - intake areas
\+ Drainage depression - level to gently inclined, long, narrow, shallow open depression with smoothly concave cross-section, rising to inclined side slopes.
† McDonald RC, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne.

## EROSION (e)

**Effect**

Land degradation and long term productivity decline will occur on unprotected arable land due to excessive soil erosion.

**Assessment**

Soil loss will depend on soil erodibility and land slope for a particular crop and surface management system. For each soil type there is a maximum slope above which soil loss cannot be reduced to acceptable levels by erosion control measures or surface management practices.

**Limitation class determination**

Slope limits are determined in consultation with soil conservation extension and research personnel, and extension and research agronomists. The implications of the classes are:

| | |
|---|---|
| e1 | surveyed row direction only required |
| e2 | conventional parallel structures required or some surface management practices[1] |
| e3 | e2 measures and some surface management practices |
| e4 or e5 | non-arable land |

[1] Surface management practices: A range of options aimed at minimum soil disturbance, combined with the retention of harvest residue material as a surface cover.

| Soil/land attribute level | | Limitation classes for various crops | | | | | |
|---|---|---|---|---|---|---|---|
| Slope % | | Avocado, Macadamia, Citrus, Mango, Stone fruit, Lychee, Grapes, Pastures, Pecan | Sugar cane (spray) Lucerne | Maize, Sorghum, Veges, Cruciferae, Cucurbits, Asparagus, Sweet corn, Pineapple, Sweet potato, Winter grains, Summer grains, Cotton | Navybean, Peanuts, Potato, Soybean, Beans, Mungbeans, Chickpeas, Sunflower, Safflower | Furrow irrigated Sugar cane | Furrow irrigated other crops |
| Very stable soils: Ferrosols | | | | | | | |
| | Code: | | | | | | |
| 0 | E0 | 1 | 1 | 1 | 1 | 1 | 2 |
| 0–2 | E1 | 1 | 1 | 1 | 1 | 2 | 3 |
| 2–5 | E2 | 1 | 2 | 2 | 3 | 3 | 4 |
| 5–8 | E3 | 1 | 2 | 3 | 4 | 4 | 5 |
| 8–12 | E4 | 2 | 3 | 4 | 5 | 5 | 5 |
| 12–15 | E5 | 2 | 4 | 5 | 5 | 5 | 5 |
| 15–20 | E6 | 3 | 5 | 5 | 5 | 5 | 5 |
| 20–30 | E7 | 4 | 5 | 5 | 5 | 5 | 5 |
| >30 | E8 | 5 | 5 | 5 | 5 | 5 | 5 |
| Stable soils: Vertosols, clayey surfaced Dermosols, coarse surfaced well drained Dermosols, Chromosols, Rudosols and Kandosols | | | | | | | |
| | Code: | | | | | | |
| 0 | A0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0–2 | A1 | 1 | 1 | 2 | 2 | 2 | 2 |
| 2–5 | A2 | 1 | 2 | 3 | 3 | 3 | 3 |
| 5–8 | A3 | 2 | 3 | 4 | 4 | 5 | 5 |
| 8–12 | A4 | 3 | 4 | 5 | 5 | 5 | 5 |
| 12–15 | A5 | 3 | 5 | 5 | 5 | 5 | 5 |
| 15–20 | A6 | 4 | 5 | 5 | 5 | 5 | 5 |
| >20 | A7 | 5 | 5 | 5 | 5 | 5 | 5 |
| Unstable soils: Sodosols, Hydrosols, Podosols, Kurosols, loamy surfaced Dermosols and Tenosols | | | | | | | |
| | Code: | | | | | | |
| 0 | B0 | 1 | 1 | 1 | 1 | 2 | 3 |
| 0–1 | B1 | 1 | 1 | 2 | 3 | 2 | 3 |
| 1–3 | B2 | 1 | 2 | 3 | 4 | 3 | 4 |
| 3–5 | B3 | 2 | 3 | 4 | 5 | 4 | 5 |
| 5–8 | B4 | 3 | 4 | 5 | 5 | 5 | 5 |
| 8–12 | B5 | 4 | 5 | 5 | 5 | 5 | 5 |
| >12 | B6 | 5 | 5 | 5 | 5 | 5 | 5 |

## FURROW INFILTRATION (if) (Deep drainage)

**Effect**

The amount of water applied and the rate of application as furrow irrigation must match the permeability of the soil to minimise deep drainage and to determine more suitable furrow length. Additional management requirements are associated with short furrows and waterlogging in the upper end of the furrows if furrow lengths are too long. The most suitable furrow lengths for flood irrigation needs to be determined.

Deep drainage in recharge areas or undulating landscapes can contribute significantly to watertables in lower landscape positions. The effect of deep drainage on groundwater levels can be managed on very slowly to moderately permeable soils within areas where groundwater is used for irrigation and on level plains with very slowly to slowly permeable soils where there is minimal contribution to groundwater levels from the surrounding landscape.

Furrow infiltration not used for microsprinkler/drip irrigated crops.

**Assessment**

Subsoil permeability (see w limitation) and landscape position. Indicator attributes for soil permeability include texture, grade and type of structure, sodicity, pH, salt bulge.

**Limitation class determination**

Consultation.

Limitation classes relate directly to soil permeability, landscape and whether the site is located within a groundwater area. Hydraulic conductivity (permeability) measurements are required.

| Soil/land attribute level | Limitation classes for various landscapes | | |
|---|---|---|---|
| Subsoil permeability to 1m | Undulating landscape | Level plains | Areas within a groundwater area |
| | All crops | All crops | All crops |
| V- very slowly permeable | 0 | 0 | 0 |
| S- slowly permeable | 4 | 0 | 0 |
| M - moderately permeable | 5 | 4 | 3 |
| H - highly permeable | 5 | 5 | 4 |

‘0’ (zero) = suitable, insufficient information to separate into classes 1, 2 or 3

## SOIL PROFILE RECHARGE (ir)

**Effect**

The amount of water applied and rate of application must match the infiltration characteristics of the soil in order to wet up the soil profile (recharge) and to minimise runoff.

Soil profile recharge not used for microsprinkler/drip irrigated crops

**Assessment**

Soil surface physical conditions (see p limitation), surface infiltration and soil permeability (see w limitation) are assessed. Indicator attributes of surface infiltration and permeability include texture, grade and type of structure, sodicity, pH, and any salt bulge.

**Limitation class determination**

Consultation.

Surface infiltration and soil permeability are considered in relation to slow soil profile recharge or additional management requirements. Surface infiltration (disc permeameter) and hydraulic conductivity measurements are required.

| Soil/land attribute level | Limitation classes for all land uses |
|---|---|
| **Surface condition** (Codes: see p limitation) | |
| Slow surface infiltration - hardsetting massive soils with surface textures of fine sandy loam to clay loam fine sandy and very firm consistency when dry. Code: S2 | 2 |
| Other soils. Codes : S1, S3, S4 | 1 |
| **Soil permeability to 0.5 m** | |
| (Codes: see w limitation) | |
| Very slowly permeable. Code: V | 2 |
| Slowly permeable. Code: S | 2 |
| Moderately permeable. Code: M | 1 |
| Highly permeable. Code: H | 1 |
| **Surface condition and soil permeability Combined** | |
| Hardsetting massive soils with surface textures of fine sandy loam to clay loam fine sandy (Code: S2) and slow to very slow subsoil permeability at 0.5 m (Code: V or S) | 3 |