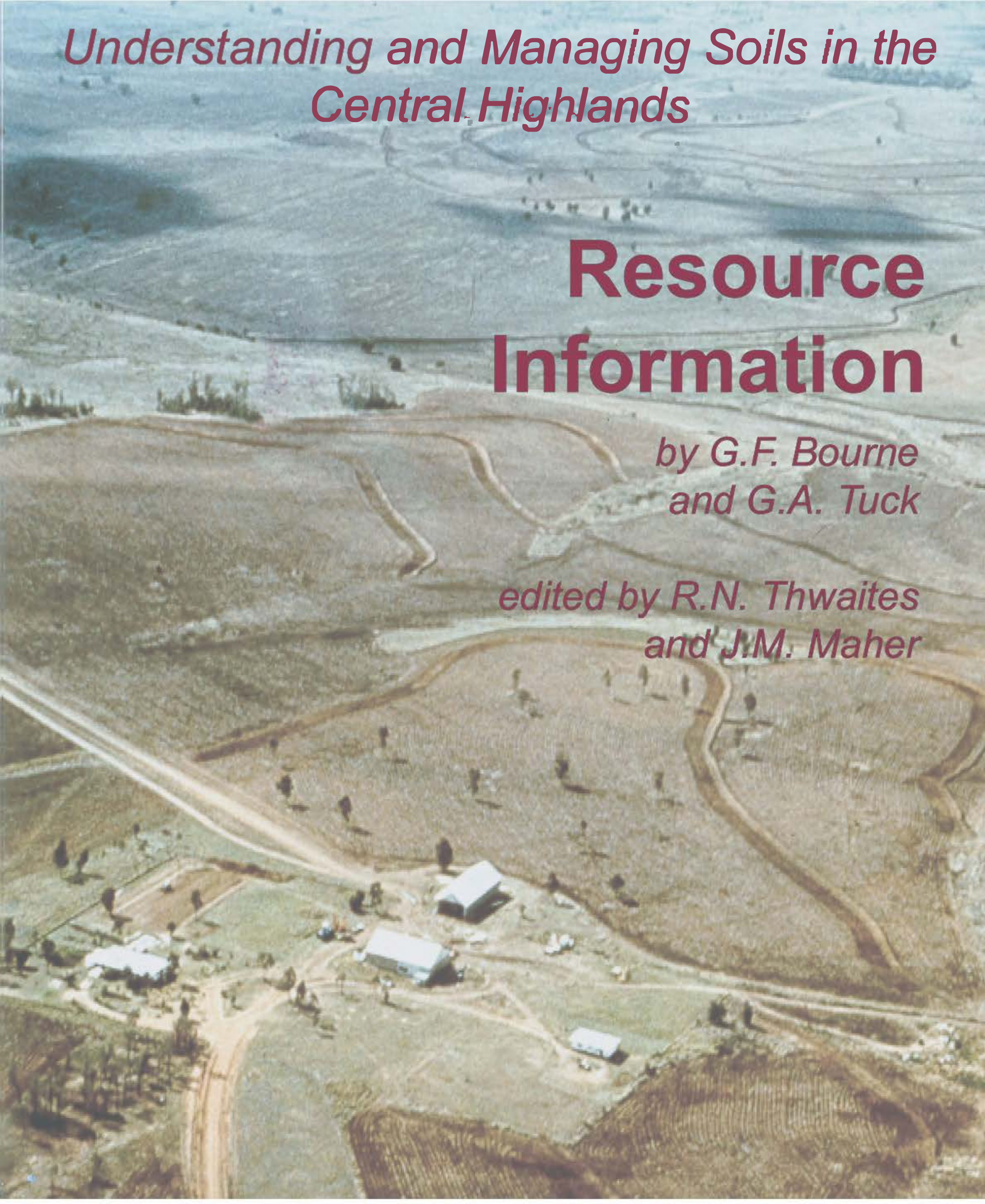

Understanding and Managing Soils in the Central Highlands

Resource Information

by G.F. Bourne
and G.A. Tuck

edited by R.N. Thwaites
and J.M. Maher

Land Management Manual Project

QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
WATER RESOURCES

Queensland Government Technical Report

For information about this report contact soils@qld.gov.au

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Introduction 1

The Land Management Manuals Project is a Department of Primary Industries 'self-help' initiative to aid decision making for sustainable land management and planning. The Land Management Manual provides a collation of currently available and up-to-date land resources data, combined with local experience and knowledge in the district.

They are designed for use by:

- extension staff dealing with land and water use issues
- farmers and farming groups e.g. landcare for property management planning and catchment planning
- planners and consultants for regional and strategic planning and for the protection of good quality agricultural land
- other interest groups, such as land valuers, educators, rural banks, and prospective property buyers

Farmers and graziers will find the summary sheets that contain land use information and recommendations for each major soil in the district particularly useful. They aim to increase the awareness, and aid the understanding, of land resources information within the community to encourage its adoption through land management recommendations. Terminology is simplified and standardised to aid the communication of land resources information within and across districts. Manuals provide a handy tool for users to identify and evaluate their soils, or those under investigation, largely for themselves. We believe this is a big step towards the linking of soils information to the management of properties or districts, and to local planning: the ultimate aim always being to support optimising production whilst minimising land degradation.

The Land Management Manual package has three major parts contained within the folder.

- The ***Field Manual***: the core and most important component of the package. It provides a summary of the region's soil and land characteristics appropriate to management and recommendations for their use. The manual provides guidelines on how best to identify the AMUs (soil groups), then use this information for decisions on appropriate land management. Various visual aids are provided for this purpose, including maps, keys, tables, summary cards and landscape and soil photographs.

- The ***Resource Information***: a reference document that emphasises the importance of soils in relation to land use and management. It provides a regional overview of climate, vegetation, geology and current land use. To support the information contained in the Field Manual, this document explains local land resource-related aspects in more detail. Information gathered from cropping areas is more reliable compared to grazing areas, because of the greater intensity of investigations in the cropping areas.
- The ***Land Resource Areas (LRA) map***: a full colour map showing the distribution of Land Resource Areas (**not** soils) within the district.

We are using the ring-binder format for these reasons:

- to include updated information inexpensively and simply,
- to allow selective removal of the AMU summary sheets for convenient use in the field or at planning meetings, and
- the more relevant and important AMU summary sheets and related information can be repositioned in a place that is more easily accessible.

Project area

The Central Highlands covers 8 645 670 ha comprising the shires of Emerald, Bauhinia and the majority of Belyando and Peak Downs. It also encompasses the eastern half of Jericho Shire (up to the watershed of the main range) and small segments of the western parts of Nebo and Broadsound Shires. The north-eastern boundary of the manual district is dictated by the limit of land resource information at a satisfactory resolution. The western boundary coincides with the CSIRO Lands of the Nogoa - Belyando Area study (Gunn et al. 1967). The major towns in the area are Moranbah, Clermont, Capella, Emerald, Springsure and Rolleston.

The project area and its relationship to manuals in surrounding regions are shown in Map 1.


CENTRAL HIGHLANDS
LOCALITY MAP
DPI
LEGEND
Central Highlands
Adjoining Manual District ROMA
Shire Boundary
Shire Name EMERALD
Map 1
BELYANDO
CENTRAL
HIGHLANDS
PEAK DOWNS
JERICHO
EMERALD
BAUHINIA
ROCKHAMPTON -
BROADSOUND
DAWSON -
CALLIDE
WANDOAN
Clermont
Emerald
Blackwater
Jericho
Alpha
Springsure
Rolleston
QUEENSLAND
CENTRAL HIGHLANDS
Cairns
Townsville
Mackay
Emerald
Rockhampton
BRISBANE
N
0
50
100km
146° 00'
147° 00'
148° 00'
149° 00'
22° 00'
23° 00'
24° 00'
25° 00'

The basis of the manual

To make the best use of this manual it is essential to understand the two major notions that are the basis of the soils information. These are the 'Land Resource Area' (LRA) and the 'Agricultural Management Unit' (AMU). They are both defined in Section 5 of the Resource Information and Section 3 of the Field Manual, but it is as well to reiterate them here.

The whole landscape is divided into six Land Resource Areas (LRAs) which appear on the map in the back pocket. These are **landscape** units, not soils, and they help to reduce the complexity of what is a very complex landscape to easily-handled proportions. The AMUs are actually soil management groups, amalgamated on the basis of their similar characteristics for land management. They are not necessarily individual soil types and they are **not** mapped. It is because little mapping has been undertaken for the district that we are producing a manual such as this.

Linking with 'land types'

A system of landscape classification exists for the management of grazing country. Like LRAs this other system, using 'land types', groups areas of land that are similar. But in this case, land types are grouped more by vegetation than by soil, geology and topography. These land types are regarded as indicators of production potential. This manual contains a reference to land types developed for the Central Highlands and links them, where possible, to the major AMUs (i.e. soil management groups) discussed in this manual.

Climate 2

Introduction

The climate of the Central Highlands is characterised by high variability in rainfall, temperature, and evaporation. Droughts, heatwaves, floods and frosts are a feature of the climate.

The most important climatic factor affecting agricultural and pastoral production is rainfall. Temperature effects crop selection and planting times in agricultural areas, while frosts can effect crop yields and pasture production.

Detailed climatic data are presented in Shire Handbooks:

- Belyando Shire - (O'Sullivan 1975)
- Peak Downs Shire - (McLaughlin et al. 1979)
- Emerald Shire - (Johnson 1972)
- Bauhinia Shire - (Cutler 1977)
- Nebo Shire - (Everett 1971)
- Broadsound Shire - (West 1973)

Rainfall

Approximate annual isohyets and monthly rainfall histograms for various centres are shown in Map 2. The mean annual long term rainfall for the main centres are shown in Table 2.1.

Table 2.1. *Mean annual rainfall and seasonal variation for eight stations*

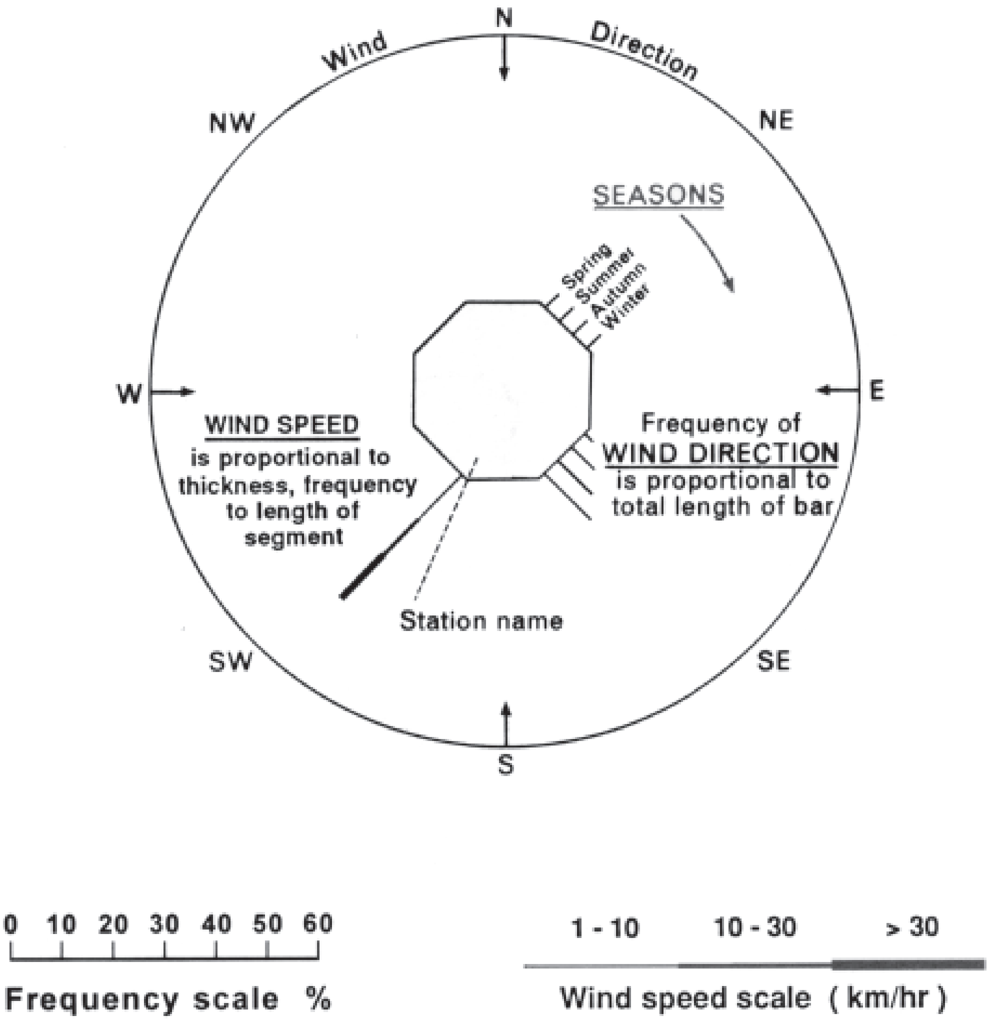
Station	Mean Annual (mm)	Apr-Sep %	Oct-Mar %	Dec-Feb %
Twin Hills	618	25	75	50
Nebo	766	25	75	49
Clermont	675	26	74	49
Capella	590	26	74	48
Emerald	639	28	72	46
Bogantungan	702	26	74	48
Springsure	685	29	71	44
Rolleston	649	30	70	43

WIND

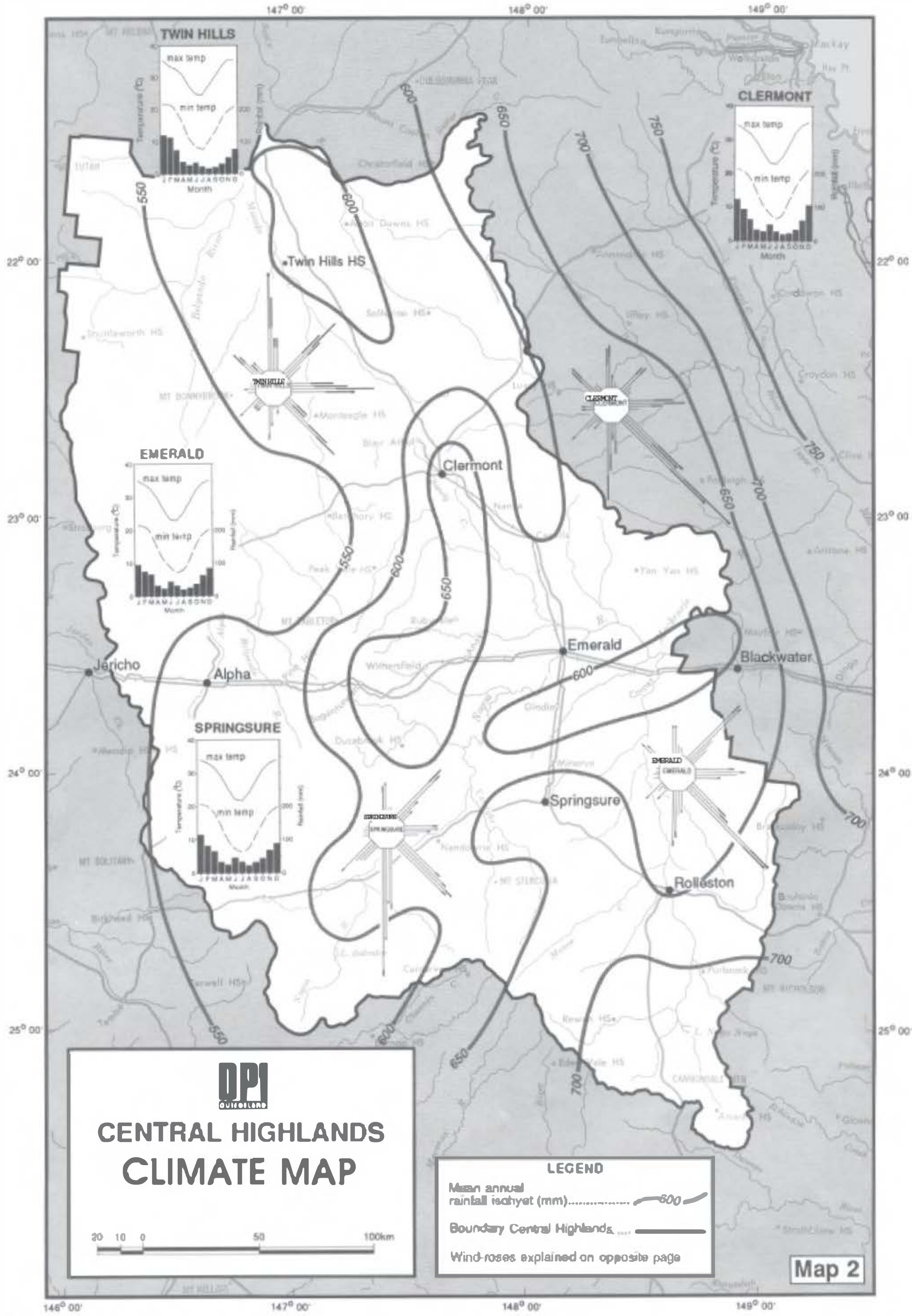
Seasonal frequencies of wind direction and speed, based on at least 21 years of records, are shown for selected stations by wind roses. Wind speeds were recorded at 9am each day. The diagram below shows how to interpret a wind rose.

Each bar represents the wind from a particular direction for a particular season. The frequency of wind from that direction is proportional to the total length of the bar.

Those bars divided into segments consider different wind speed categories. Wind speed is proportional to bar thickness. The frequency of wind speed in each category is proportional to the length of each segment.



Refer to Climate Map (Map 2)



Data source: Bureau of Meteorology 1992

Rainfall is summer dominant with 70-75% of the total annual rainfall occurring in the summer period, October to March. The winter component of rainfall gradually increases towards the south as can be seen from Table 2.1

Generally, there is a gradual decline in total rainfall from south to north and from east to west of the Central Highlands district.

Cyclones can effect the area, but only as heavy rain depressions, generally in the period from January to March. Most of the rain between September and December is from thunderstorms. The Central Highlands area experiences the highest average number of thunderstorms in Queensland. The average thunderstorm has an 8 km front and a 64 km path. Although thunderstorms are a valuable source of rainfall, their high intensities produce high runoff and associated soil erosion problems.

Mean monthly rainfall is highest and daily falls are heaviest, during January and February. This is also the best time for well-developed troughs to occur. They extend across the area after developing from low pressure centres over the northern part of the continent. They coincide with the probability of easterly approaching cyclones.

The large spatial variability of thunderstorm rains, and the erratic nature of the so-called ‘general rains’ from January to March, can lead to considerable variations in seasonal conditions.

An index termed EI (erosion index) gives an indication of the potential for soil loss from bare surfaces. This index is the product of the total storm rainfall energy and the storm’s maximum 30 minute intensity.

Data for both monthly and annual distribution of erosivity for Twin Hills, Clermont, Emerald and Springsure have been estimated from Rosenthal and White (1980). These values are presented in Figure 2.1.

The erratic nature of the rainfall, its short duration and high intensity (see Figure 2.1) are all important considerations in the suitability of cropping systems in different parts of the Central Highlands. Crops are generally not planted in spring due to the soil profile not wetting up enough from the high intensity, short duration thunderstorms, as well as

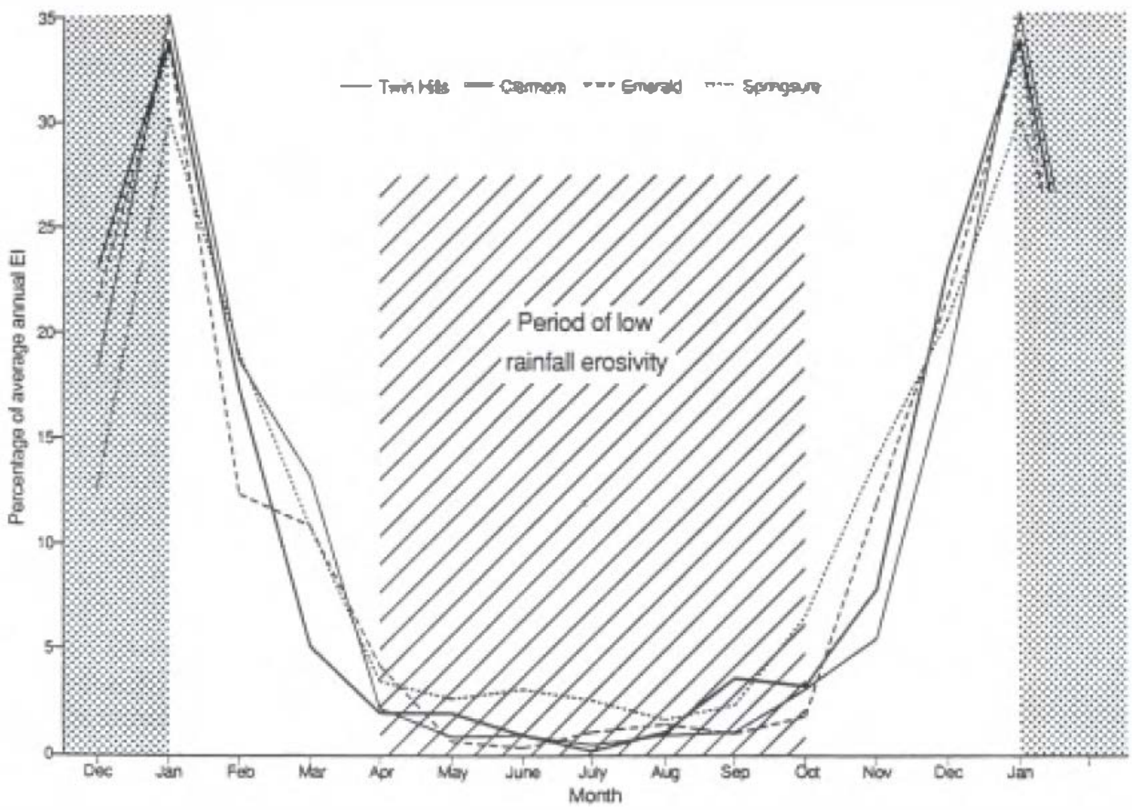


Figure 2.1. *Erosion Index from four centres in the Central Highlands*

the lack of likely follow-up rain. Even after conventional planting times, lack of follow up rain can be a problem.

Because of the high probability of dry periods occurring, summer and winter crops rely on stored soil moisture to attain a satisfactory yield. Therefore fallow management practices that improve infiltration and reduce runoff and evaporation are very important measures which affect fallow efficiency and potential crop yield.

Temperature

Long term mean maximum and minimum monthly temperatures for four centres in the Central Highlands are shown in Figures 2.2 and 2.3 and Appendix II. A comparison of the figures shows that there are only minor differences between the major centres.

Heatwaves and frosts are a feature of the Central Highlands climatic environment. Their effects are more pronounced on crops but pastures and stock are also affected by these climatic extremes.

Heatwaves

A heatwave is defined as three consecutive days over 38°C. These constitute a real hazard if the crops are at a particularly sensitive stage. Heatwaves occur most commonly in December and January. They can start in late October when there is a 1 to 5% chance of them occurring. In early November the probability rises to 14% and continues to rise to 19% in early January. In February the probability of a heatwave drops to 3 to 9% and in March there are no heatwaves. (Rosenthal and Hammer, 1979).

Frost

July and August are the months of greatest frost risk. The chance of getting a 0°C frost on any one day in the week is less than 50% at any time of year. The earliest 0°C frost at Emerald is April 29 and latest is September 9th (Hammer and Rosenthal, 1978).

The frequency and severity of frosts varies considerably from one locality to another. Therefore the frost statistics at Emerald Post Office are probably misleading. Many localities in the Central Highlands have a higher probability of severe frosts than the official figures suggest. Often the lower slopes experience heavy frosts while the upper slopes remain relatively frost free.

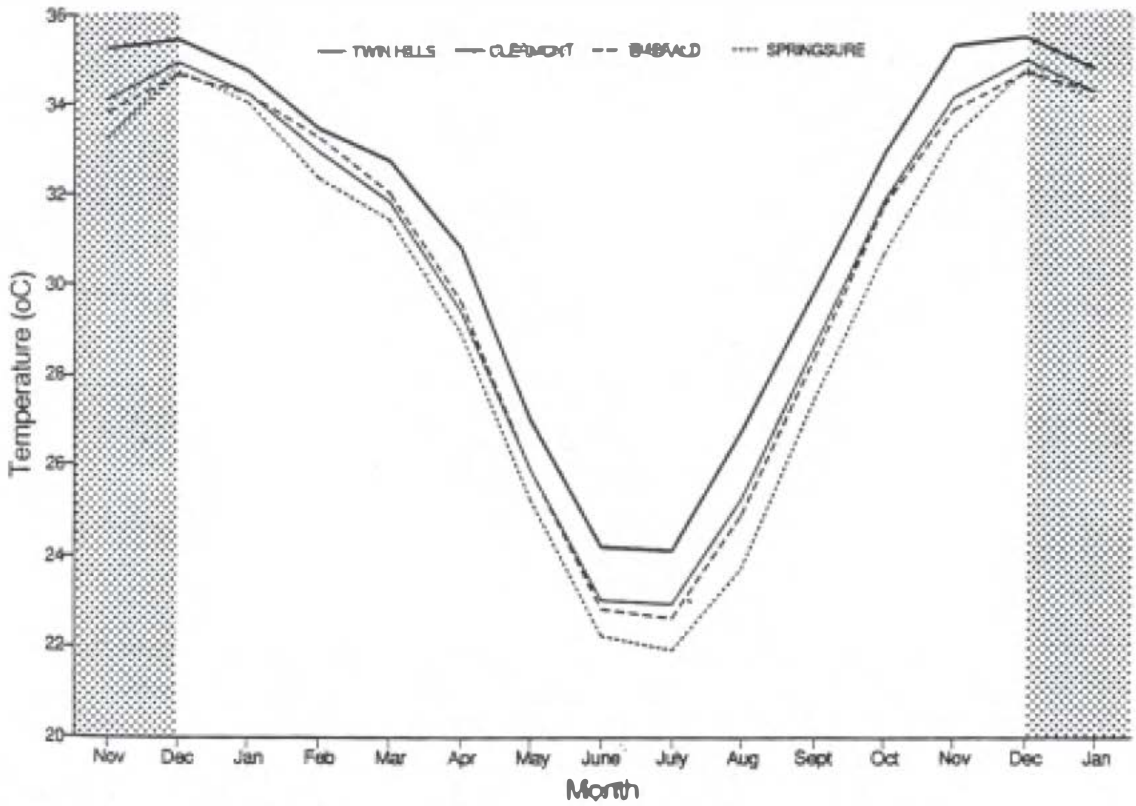


Figure 2.2. *Mean daily maximum temperature*

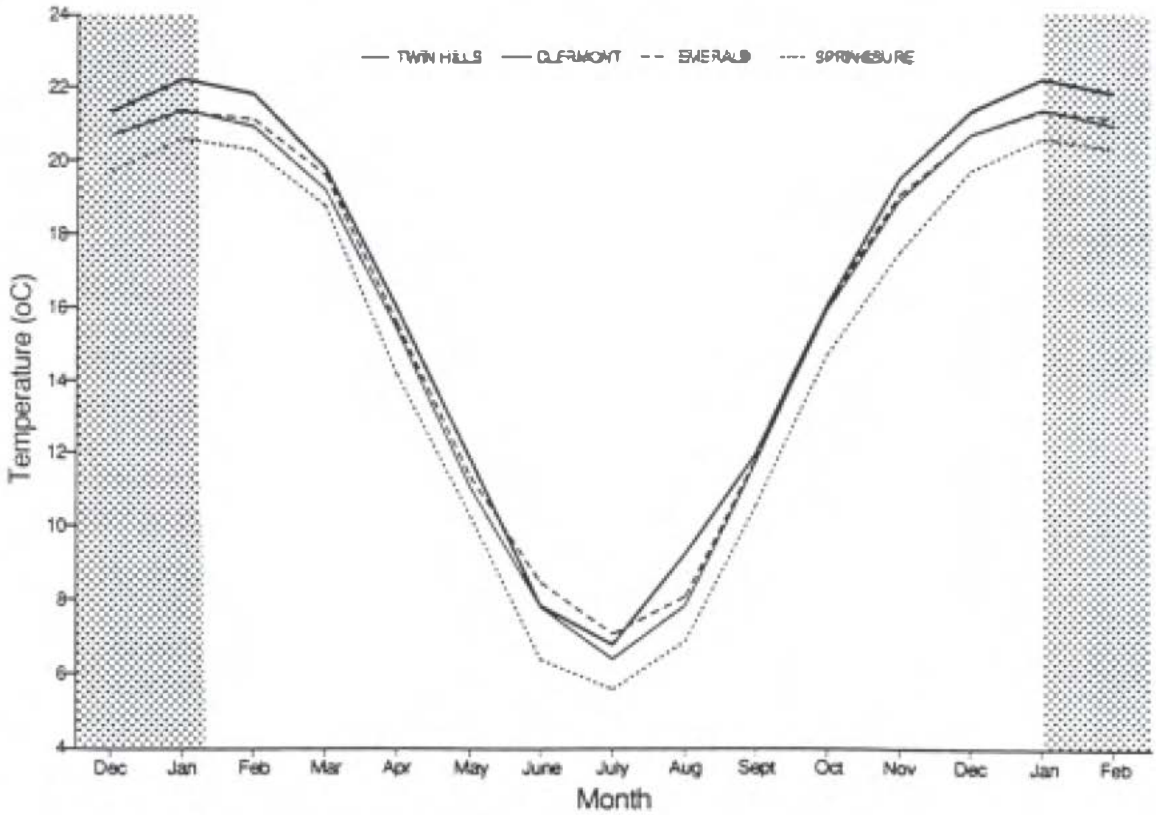


Figure 2.3. *Mean daily minimum temperature*

Evaporation

The long term average daily pan evaporation figures are shown in Table 2.2. This shows that November and December are usually the two months of greatest evaporation and that daily rates of 7 to 9 mm are not uncommon. However daily evaporation can exceed 11 mm.

Table 2.2. *Average daily pan evaporation for four stations (Class 'A' pan) mm/day*

	Month of the year												
Centre	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
Twin Hills	8.0	7.0	6.3	5.2	4.0	3.3	3.4	4.6	6.1	7.5	8.6	8.3	6.0
Clermont	7.8	6.9	6.1	5.1	3.9	3.1	3.3	4.3	5.7	7.2	8.1	8.3	5.8
Emerald	7.8	7.2	6.3	5.0	3.8	3.1	3.2	4.2	5.5	7.1	7.9	8.0	5.8
Springsure	8.0	7.3	6.3	5.1	3.8	3.0	3.2	4.2	5.7	7.1	8.0	8.1	5.8

In the winter period, evaporation is considerably lower and less variable. Daily evaporation of 3 to 5 mm is usual.

Because of high evaporation rates, water storages for stock or irrigation need to have reliable watersheds and hold great depths of water. There are times in the pastoral areas when it is stock water which is limiting animal production, not pasture availability.

Climate in relation to agriculture

Climate is a major factor controlling the patterns of land use and the potential agricultural and pastoral productivity within the Central Highlands.

The area is marginally situated with respect to the meteorological systems which produce more dependable rainfall to the north and to the south. Average rainfall is considerably higher during the summer months than during the winter, for the whole of northern Australia but unlike areas to the north and north-west, the winter months can provide significant rainfall. This contributes to the high degree of variability in the amount and incidence of rainfall.

It is misleading to use the average monthly and annual rainfall to determine 'growing seasons' to judge the potential productivity of a piece of land in the Central Highlands. This area is not like other parts of Australia where more clearly defined and comparatively consistent wet and dry seasons occur.

By far the most important way in which climate affects pastoral or agricultural production is through its control over the availability of soil moisture for plant growth. The occurrence of sub-optimal temperatures during winter months is also important, particularly for native pasture species. Also, heatwave conditions during summer restrict growth and can cause severe crop damage. However, temperature as such does not assume the same overriding importance as a control over plant growth, as does rainfall. Temperature variation or extremes are generally less hazardous aspects of the climate than the erratic nature of rainfall, which produces large temporal fluctuations in soil moisture and hence in crop and pasture yields.

Pastures

The growth of both native and improved pastures is controlled by sub-optimal temperatures during the winter months and by the marked seasonal distribution of rainfall.

With the onset of rains and warmer temperatures in early summer grass growth is rapid, generally producing a surplus of stock feed. During the summer period, growth can be restricted by heatwave conditions and limiting moisture. Following the flowering stage there is a rapid decline in growth and pasture quality. During the winter months native pasture growth is negligible regardless of moisture conditions because of low minimum temperatures and frost. Improved pasture species will make some growth in those areas not affected by frost, if moisture is available. Any winter rain falling on hayed-off surplus summer growth causes further deterioration in pasture quality.

Summer crops

The rainfall and temperature interaction has resulted in a variation in planting date compared with more traditional grain growing areas. Unreliable early summer rain together with the higher probability of heatwaves means that late summer, early January to late February, is the preferred period to plant summer crops. Heatwave data supports this: the real danger months of December and January will not coincide with the critical preflowering period, though young seedlings may be burned off. In addition, the average date of first frost in mid-June allows the traditional summer crops, with a four month growing period, to be accommodated in the period allowed with fair safety from frost.

Winter crops

With winter crops the reverse applies. Unreliability of winter rain means that farmers will sow early in April and May if the opportunity is presented. Subsequent rain, which would be preferred for planting further south, is used here to put down secondary roots. A mild winter environment grows a soft plant which is highly susceptible to frost. This early planted winter crop is in great danger from July frosts. Furthermore, winter crops finish a little earlier than further south and the season breaks a little later. This means a generally safer harvesting period than that experienced on the Downs.

With the evaporation rate more than twice the annual rainfall, and much of the annual rainfall being lost through runoff from high intensity storms, the importance of increasing infiltration to provide plant available water is clear. Management of crop and pasture land should be aimed at reducing runoff, evaporation and increasing infiltration. This is particularly important on crop land where the benefits of retaining stubble on the surface have been proven.

Drought

Droughts are a normal feature of the area. Drought is defined as an occasion when climatic variations are so severe, that the risks greatly exceed what would be considered to be an acceptable, manageable level of commercial risk. Existing records suggest that there is a probability of a severe event of this nature occurring once in every 10 to 15 years. During droughts, crops are not planted, and dry spells greatly reduce grain yields and affect the time of planting.

Dry periods usually occur every winter. The length of this period is normally determined by the arrival of spring storms. If these storms are late or fail to occur, pasture quality and quantity is poor by October to November.

Geology 3

Introduction

The occurrence of the soils in relation to some of the important factors that have influenced their development is discussed briefly in this section.

This summary has been taken from Gunn et al. (1967) and Story et al. (1967).

Landform development

After the formation of extensive basalt sheets in early Tertiary times, prolonged erosion stripped much of this basalt or reduced it to relatively thin sheets such as those found east of Clermont. The basalt was only extensively preserved on the Buckland Tableland in the south of the region. On the pre-basalt rocks erosion was largely controlled by contrasts in rock type. Areas of softer rocks were eroded to form lowlands or valleys, leaving the harder rocks as scarps and hills.

Later in the Tertiary, erosion continued to operate but its effect on the landscape changed significantly. The erosion material was no longer exported from the area but largely accumulated on the lowlands. Sandy and loamy sediments were derived from sandstones, conglomerates formed gravelly sediments, while shales and basalt formed clays. The result was a gently undulating land surface that was depositional over extensive lowland areas and erosional on limited higher areas.

Deep weathering (in situ chemical weathering) was associated with this gently undulating Tertiary landscape. It penetrated deeply below the surface and extensively altered the nature of the rocks. Silica was mobilised and redeposited in the weathering profile as horizons and masses of quartzite. Lateritic profiles consisting of an iron-rich zone over mottled and pallid zones (resulting from kaolinisation) developed widely.

Subsequently, the Tertiary land surface and weathered zone were partially eroded and in places removed entirely. This erosion resulted in the development of a topographic sequence of soils with associated vegetation types on a wide range of rocks, particularly the Tertiary sediments. Little removal has taken place in the west where the gently undulating to level Tertiary land surface with loamy or sandy soils remain. Partial removal of the Tertiary land surface has taken place in the centre, east, and north of the area.

Consequently, all parts of the soil sequence and also some areas of fresh pre-Tertiary rocks are represented. Almost complete removal in the south of the area has given a landscape conditioned by the type of exposed unweathered pre-Tertiary rocks.

Renewed deposition, associated with the erosion in late Tertiary times formed extensive clay sheets in the north-east and sandy fans in the north-west, while gravel terraces formed along the major streams. Two phases of alluvial deposition, separated by a period when wind deposition was significant, occurred in the Quaternary.

Soil formation

Past climatic and geomorphic influences

The nature and distribution of soils occurring on the remnants of the Tertiary land surface, or on erosional and / or depositional landscapes within the deeply weathered zone, have been influenced more by past climate and geomorphic history than by any other factors. In particular, the effect of deep weathering on parent rocks tends to mask rock type differences in all except quartz sandstones. The dominant soils fall into three main groups which occur generally in a sequence from ridge crest to valley bottom. On the more or less intact Tertiary surface red and yellow earths predominate. Where erosion has exposed the underlying weathered zones, soils with abrupt textural contrasts between surface soil and subsoil (duplex soils) occur in mid sequence and cracking clay soils, commonly with gilgai microrelief, occur in lower lying areas.

Red and yellow earths together with deep uniform coarse-textured soils on fans derived from them are dominant in the Plateaus LRA. These highly leached soils, rich in iron and aluminium and kaolinitic clay, often with much concretionary ironstone, are believed to have formed under more humid climatic conditions than those of the present day.

Duplex soils are dominant on the upper to lower parts of the Tertiary weathered zone. The soils commonly have a dominance of exchangeable sodium and magnesium ions in the clayey subsoils. Other soils in this group have clearly formed by the deposition of coarse-textured materials over older clays. These two types of duplex soils appear to occur in close association and they support the same vegetation.

Cracking clay soils are dominant on the lower parts of the Tertiary weathered zone in sedimentary rocks and basalt. They cover the Undulating Scrub Plains LRA and have extensive areas of strongly developed gilgai microrelief.

Rock type and relief

In the erosional areas largely below the Tertiary weathered zone, soil type and distribution are governed mainly by rock type and relief. In areas with mountainous to hilly relief, shallow rocky soils predominate. They occur mainly on resistant quartz sandstones but also on volcanic and metamorphic rocks in the Ranges LRA.

Shallow duplex soils with some cracking clays occur in narrow bands on slopes which follow the line of direction of the folded sedimentary rocks. These are mainly in the Eucalypt Duplex Plains LRA with undulating to hilly relief. Deep duplex soils are dominant on partially weathered shales and sandstones, and on granite.

Basalt and shales in the Undulating Downs and Undulating Scrub Plains LRAs both give rise to fine-textured soils low in quartz. Dark brown and grey-brown soils occur on bouldery ridges and cracking clay soils have developed in valleys. Undulating land in the south has dominantly dark brown and grey-brown soils derived mainly from shales. Dark cracking clay soils are dominant on basalt and shales in the east and south. Where the relief is undulating to level, mainly deep soils occur, while shallow soils dominate on hilly relief.

Landform, mode of deposition, and the nature of source materials largely determine soil distribution on alluvia. Cracking clay soils are dominant on lower alluvial plains which are subject to seasonal flooding. These are adjacent to streams that rise mainly in areas of basalt, shales, and basic sediments. Duplex soils and alluvial red earths occur on moderately well-drained upper plains and terraces of streams with source areas of predominantly quartzose rocks.

Land use overview 4

History of land use

Ludwig Leichhardt was the first European to enter the area on his journey from Jimbour, on the Darling Downs, to Port Essington, in 1844-45. He journeyed through what are now the shires of Bauhinia, Emerald, Peak Downs and Belyando. In December 1845 Leichhardt was followed by Sir Thomas Mitchell before he again returned to the area in 1847. It was Leichhardt who opened up large tracts of land in the area primarily for grazing.

Grazing

The district developed as large sheep runs over the Open Downs country (now referred to as the Undulating Downs Land Resource Area, see Section 5). Some tracts were split off large runs in the 1884 Land Act, but these holdings proved too small and were quickly consolidated into bigger blocks.

The Open Downs grassland is normally dominated by bluegrass on dark cracking clay soils. It is good stock feed and several other species of grasses and legumes (annuals) contribute to a high grade pasture. The quality of pasture declines with maturity, so that, in winter, it has low feed value.

This was remedied by early pastoralists who burnt the pastures as soon as possible, after the wet months. This provided a nutritious green shoot for winter. However, the long term effect was harmful. The burned strips were overgrazed by sheep which led to the gradual disappearance of the preferred species and their progressive replacement by unpalatable species.

After the 1914-15 drought, white speargrass (*Aristida leptopoda*) became conspicuous on the Downs. This is a short-season, unpalatable grass whose seeds can penetrate the flesh of sheep to the shoulder blades, and can even enter the abdominal cavity.

Selected grazing of the burnt patches led to the replacement of the bluegrass (mainly *Dichanthium sericeum*) by the less palatable white spear (*Aristida leptopoda*) and yabila (*Panicum queenslandicum*) grasses.

As the proportion of pest grasses increased, graziers burnt even more frequently, not only to prevent them from seeding, but also because only in the very young growth stages could any feed be obtained from them. Thus the graziers were caught in a vicious circle; burning was both the cause, and supposedly, the cure.

Yabila and white speargrass are more drought resistant than bluegrasses. The period 1930 to 1940 was a series of poor seasons and bluegrass declined rapidly in this time. By the 1940s white speargrass was regarded as second only to dingoes as a pest of sheep. Indeed, it was these two factors that forced a general changeover from sheep to cattle.

In the late 1950s, the development possibilities of the brigalow scrub lands in the Fitzroy Basin were investigated. Consequently, the Fitzroy Basin Land Development Scheme was established in 1962. The soils range from dark heavy cracking clays to duplex alluvial soils. The poorer of these duplex soils have shallow surface horizons. Brigalow Area Scheme 2 took in part of Bauhinia and Emerald Shires to make approximately 40 new blocks. Brigalow Area Scheme 3 (started in 1969) took in parts of Belyando, Broadsound and Nebo Shires to create 130 new blocks.

This 'Brigalow scheme' has had a major effect on the settlement and development of the Central Highlands. Large areas which were dense brigalow scrub in the 1950's are now tracts of highly productive improved pasture.

Agriculture

The agricultural potential of the region's Open Downs country was recognised soon after European settlement.

The Department of Agriculture and Stock (now the Department of Primary Industries) established the Gindie State Farm about 30 km south of Emerald in 1897. This was sited on dark cracking clays of the Undulating Downs LRA because of its ease of development for cultivation. Crops planted, prior to its closure in 1932, included wheat, barley, oats, maize, sorghum, panicum, millet, cowpeas, field peas, lucerne and cotton. The success of these crops was dependent on the vagaries of the weather and pests, including locusts. With a few exceptions, the results did not motivate a pastorally oriented community to take up cropping.

The setting up of the Queensland British Food Corporation (QBFC) following the second world war really initiated the Central Highlands grain cropping industry. Cultivation was almost exclusively on the Undulating Downs LRA. The plan was to produce grain sorghum for pig production in Queensland and for export to Great Britain. However, political interference, cumbersome administration and the variability of the Central Queensland climate, brought about the downfall of the Corporation.

While the achievements of this large scale cropping venture were unimpressive, the scheme led to the subdivision of existing holdings. The resulting influx of farmers (many with cropping experience) soon made good use of the large equipment pool sold up after QBFC operations ceased in 1954.

Arable land was put up for selection on a restricted basis during disposal of the land between 1954 and 1956. QBFC deserves credit for having initiated the expansion of agriculture on the Open Downs country which is now an important grain growing area.

Mining

Leichhardt found coal outcropping in the Blackwater area during his travels in the 1840s. By 1935 more than one million tonnes had been mined from the Blackwater-Bluff area. Coal was also discovered at Blair Athol in 1864.

Copper was discovered at Copperfield, south-west of Clermont, in 1862 but was exhausted by 1887.

Gold was discovered near Clermont in the 1860s as well as sapphires and other gems at Anakie in 1873.

These mineral finds had a profound effect on the exploration and settlement of the pastoral areas. In fact Clermont, Anakie and Blackwater were settled as towns only because of the mineral rush.

Present land use

In 1989 the area developed for cropping was approximately 7% of the total area of the Central Highlands (Table 4.1).

Table 4.1. *Central Highlands land use (1981-91) on a shire basis*

	Belyando		Peak Downs		Emerald		Bauhinia	
	1981	**1991**	**1981**	**1991**	**1981**	**1991**	**1981**	**1991**
Agricultural establishments	195	195	157	157	196	196	239	239
Croplands ha x 1000	115	154	94	124	88	90	117	144
Natural grasslands (grazing) ha x 1000	305	266	161	131	61	59	235	208
Cleared or partly cleared (grazing) ha x 1000	225	620	20	118	93	202	297	572
Timbered (grazing) ha x 1000	1478	1083	281	183	478	369	863	588
State Forests and Reserves ha x 1000	68	68	24	24	38	38	91	91
Unspecified ha x 1000	817	817	230	230	265	265	853	853
Total ha x 1000	**3008**	**3008**	**810**	**810**	**1023**	**1023**	**2456**	**2456**

(Source: ABS 1981 and 1991, QFS 1992 and LCB 1992)

Grazing

The Central Highlands produces the greatest amount of cattle in the state (Table 4.2).

Breeding and fattening is the major beef enterprise. Bullocks are turned off native pasture as ‘fats’ at 3½ to 4 years of age. With improved pasture, the age of turn off is between 2½ to 3 years (approximately 300 kg dressed weight), and in the farming areas where crop stubble and failed grain crops are available, the age of turn off is 2 to 2½ of age (approximately 240 kg dressed weight).

Breeding and selling ‘stores’ is conducted on properties which have an insufficient area of better class country for fattening or on underdeveloped brigalow scrub country.

Table 4.2. *Beef cattle numbers for shires of the Central Highlands for the years 1981 and 1991.*

	Belyando	Peak Downs	Emerald	Bauhinia
1981	251 500	72 270	113 410	268 470
1991	311 050	100 475	147 136	316 952

(Source: Australian Bureau of Statistics, 1981 and 1991)

Stores are generally sold from these properties at 18 to 30 months of age. Feedlotting is a common practice along with opportunist store buying. Approximately 80 per cent of the cattle in the Central Highlands are marketed to suit export requirements. The balance is sold for local trade with a sprinkling of stores sold to the Dawson Valley (to the south east) and the Darling Downs area.

Cropping and irrigation

The major crops produced in the Central Highlands in terms of area used and production are listed in Table 4.3. The cultivation of other crops, such as safflower, rape, linseed, peanuts, maize, triticale, barley, oats, and horticultural crops shows the diversity of cropping alternatives for the Central Highlands area.

Table 4.3. *Production of major crops (5 year average to March 1990)*

Crop	Area (ha)	Production (t)	Average (t/ha)
Wheat	109 096	196 120	1.80
Grain sorghum	111 167	171 277	1.54
Sunflower	71 991	58 827	0.82
Chichpeas	2 769	3 899	1.41
Mungbeans	3 225	2 253	0.70
Cotton (irrigated)	9 008	11 938	1.33
Cotton (dryland)	7 318	2 843	0.39

(Source: Australian Bureau of Statistics 1990)

The total area under cultivation is currently stable with relatively small areas growing forage crops. Forage crops and crop stubble are important for the ‘finishing’ of cattle.

The area planted to irrigated cotton is increasing with changes to water allocation and the development of suitable land downstream from present production areas.

With the continuing rundown in the fertility of a lot of the cropping soils, the area being planted to leguminous crops (chickpeas and mungbeans, for example) is increasing.

Mining

A large proportion of the coal-rich Bowen Basin lies in the Central Highlands and coal mining, both open cut and underground, is the major mining operation in the area. Currently, all the open cut mines are on non-arable land. However, this will not always be the case as there are proven coal reserves under, and coal mining leases over, most of the cropping lands of the Central Highlands.

There are proven reserves of natural gas around Springsure and Rolleston and some of these have been tapped into the Jackson-to-Gladstone pipeline. There are reserves of soda ash south of Comet.

The Anakie Gemfields are a well known supplier of gems and semi-precious stones. It is the largest sapphire producing area in Australia.

Gold mining occurs north of Clermont and takes place spasmodically according to fluctuations in the price of gold.

Forestry

There are 221 000 ha of State Forest and Timber Reserves in the Central Highlands (see Table 4.1). These are all native eucalypt forests and there are usually grazing leases granted over them.

The Queensland Forest Service (QFS) also administers quarries and this returns approximately 65% of the money paid to QFS for timber and gravel. A further 25% of sales comes from railway sleepers and fencing timbers.

Horticulture

With the abundant supply of good water for irrigation and the presence of suitable soils, the horticultural industry, centred around Emerald, has an assured future. Even at this early stage, the single largest citrus orchard in Queensland is almost in full production in the Emerald Irrigation Area. There are also large commercial vineyards and avocado plantations as well as melons, sweet corn, pumpkins and tomatoes currently being produced.

Distance to markets and lack of continuity of production are the major obstacles to the Central Highlands becoming a major producer of some of these specialised crops.

Apiculture

Beekeeping is undertaken extensively throughout the area. Bees are very important in ensuring the pollination of sunflower crops. The large areas of flowering native eucalypts and the sunflower crops ensure that beekeeping is a viable industry.

The land resources 5

Introduction

The land resources of the Central Highlands have been previously described at various scales of intensity in terms of geology, soils and vegetation. The work was done for a variety of purposes. This manual seeks to draw on all that existing data to form the basis to setting sound land use management guidelines for the region.

The classification of land resources is at two levels of intensity so that land management requirements can be determined for specific types of land.

Land Resource Areas (LRAs) are broad landscape units made up of groups of different soils developed from related geological units with recurring patterns of topography and vegetation. These are mapped.

Agricultural Management Units (AMUs) are groups of soils with similar landforms, vegetation and agricultural potential. Soils within an AMU can be managed similarly. Each LRA is made up of one or more AMUs.

The principal basis for each AMU is similarity of management requirements. Therefore it is possible to have various soil types included.

Photographs and description of a soil for each AMU are included in the *Field Manual*. They are designed to illustrate the most representative example of soils within that group. The variations within AMU groups are discussed in the following sections. AMUs are not mapped.

Land Resource Areas

Six LRAs cover the Central Highlands district. A map showing their location is provided in the *Field Manual*. Key 1 is for the identification of LRAs separate from the map, based on their physical characteristics. A key to the AMUs, which make up each LRA, is provided as Key 2. Both keys are to be found in the *Field Manual*.

The LRAs described below were defined in terms of parent material and landform similarities using the work of Gunn et al. (1967) and Story et al. (1967).

Alluvial Plains LRA. Includes the range of soils formed on recent alluvium. Plains of deep, heavy clays with brigalow and coolibah scrub form the most widespread and agriculturally important AMU of the Alluvial Plains LRA. Another, less widespread but equally productive group are the open coolibah plains of mostly lighter-textured clay with a deeper, finer self-mulching surface.

A range of soils with marginal to no potential for cropping also occur throughout this LRA. They include deep uniform loams and sands, duplex soils and hard setting, poorly drained clays.

Undulating Scrub Plains LRA. Comprises soils formed from the deposition of weathered fine-grained sediments. The high degree of soil variation occurs due to the variety of parent material and weathering regimes. As a result, six major, and two minor AMUs make up the group.

Eucalypt Duplex Plains LRA. Extensive areas of sandy and loamy duplex soils occur throughout the area. Although the soils display considerable variation, it is possible to simplify the range into two major AMUs with similar management requirements and potential.

Undulating Downs LRA. Includes the heavy clay soils formed *in situ* on basalt and fine-grained sedimentary rocks. Depth to parent rock and lithology are the major diagnostic AMU attributes.

Plateaus LRA. The deep red and yellow sandy earths and duplex soils with a deep A horizon, and sands formed from lateritised sedimentary rock make up this LRA. Included are relict alluvial fans. A specific feature is the diversity of vegetation types which occur.

Ranges LRA. Includes the range of shallow soils associated with mountains, hills, ridge lines and dissected plateaus which have been included within a single AMU.

Agricultural Management Units

Eighteen AMUs are described for the Central Highlands districts. The AMUs are listed in Table 5.1 under the LRA with which they are predominantly associated.

A feature of the depositional plains of the region is the complexity of soil types within small areas. It is common to encounter situations with three to four AMUs within a single paddock. In such cases the overall complexity becomes a determining factor for land use in addition to attributes of dominant AMUs.

Depth to *high* subsoil salinity is an important factor for agricultural suitability of some clay soils of the Alluvial Plains and Undulating Scrub Plains LRAs. This high subsoil salinity is commonly referred to as the salt bulge. Apparently well-suited brigalow soils can have poor, water-

Table 5.1. *Relationship of AMUs to LRAs*

LRA	AMUs: Major Occurrence	AMUs: Minor Occurrence
Alluvial Plains	Adelong, Moramana, College	Dooruna, Isaac, Lascelles, Lonesome, Rolleston, Turkey Creek
Undulating Scrub Plains	Rolleston, Picardy, Springton, Turkey Creek, Glengallan, Glen Idol	Adelong, Lonesome
Eucalypt Duplex Plains	Lascelles, Duckponds	Glengallan, Turkey Creek, Glen Idol
Undulating Downs	Orion, Jimbaroo	Kia-Ora, Glen Idol, Moramana
Plateaus	Duckponds	Glen Idol, Highlands, Lascelles
Ranges	Highlands	Lascelles, Glen Idol

stressed crops in many years. A prime cause for this is the reduced effective rooting depth due to the salt bulge preventing exploitation of deeper soil moisture and nutrients by the plant roots. Soils with shallow depth to the salt bulge are dependent on seasons with frequent rainfall to produce satisfactory crops. Clay soils in which the salt bulge may be a prominent factor are Lonesome, Rolleston, Dooruna, College and, partially, Turkey Creek AMUs.

While such restrictions may be deduced from field evidence, such as stunted trees or subsoil mottling and structure, laboratory electrical conductivity (EC) tests are needed to confirm the depth of high salt levels in the soil profile. The tests are quick and inexpensive. Often the only real difference between a highly productive brigalow soil, eg. Picardy AMU, and a less productive soil, eg. Rolleston AMU, will be the depth to the salt bulge.

Soil families described within CSIRO land systems surveys (Gunn et al. 1967 and Story et al. 1967) formed the basis for AMU definition. They were further refined from later higher intensity surveys where possible and their distinguishing features are given on the summary sheets in the *Field Manual*.

The technique for identifying AMUs is explained in the *Field Manual*. The major morphological, physical and chemical attributes for each AMU are discussed below and summarised in Tables 5.2, 5.3 and 5.4.

Table 5.2. *Distinguishing morphological features of the AMUs*

AMU	Soil Classification	Colour	Texture Profile; Depth	Other Profile Features	Landform
Adelong	Black earth, grey clay Ug 5.16, 5.24	Dark to grey surface over dark to grey subsoil becoming lighter and slightly mottled at depth	Uniform medium to heavy clay; > 1.5 m	Self-mulching and deeply cracking with alkaline reaction trend	Level alluvial plains
College	Grey and brown clay and non-cracking clay Ug 5.24, 5.13, Uf 6.3	Grey-brown to dark surface over yellow-brown to grey subsoil, red or yellow mottles at depth	Fine sandy clay surface over heavy clay; generally > 1.2 m; may include gravel layers	Soil reaction trend alkaline becoming acid with depth; hard setting or coarse mulching surface over hard blocky subsoils.	Level alluvial plains and levees
Dooruna	Grey clay Ug 5.24, 5.29, 5.25	Grey over brown to grey-brown subsoil; mottled at depth	Medium to medium heavy clay over heavy clay; > 1.5 m	Coarse self-mulching surface over blocky subsoils; acid to neutral reaction trend.	Level plains
Duckponds	Massive earth, red and yellow duplex soil Gn 2.12, 2.13, Dr 2.43	Dark, red to yellow surface over red to yellow subsoil	Sandy loam to sandy clay loam surface over sandy clay to medium heavy clay subsoil; often quartz gravel layers; generally > 1.2 m	Neutral to alkaline reaction trend; firm to hard setting surface over weakly structured to coarse prismatic subsoils	Plateaus, rises and undulating plains
Glengallan	Solodic and solodized solonetz Dy 3.43, 2.33, 2.43	Dark brown to yellowish brown over mottled yellowish grey to brown subsoil medium heavy clay subsoil	Sandy loam to sandy clay loam surface < 0.2 m; abruptly changes to medium heavy clay subsoil; > 1.2 m	Hard setting surface, often bleached, over coarse columnar structured and alkaline subsoils	Gently undulating to undulating plains
Glen Idol	Red-brown duplex and associated non-cracking clay Dr 4.13, Uf 6.3	Red to reddish brown surface over red to reddish brown subsoils	Clay loam to sandy clay loam over medium to medium heavy clay; generally > 0.9 m	Generally hard setting surface and no bleach; moderate prismatic structured subsoil; alkaline subsoils; carbonate often present	Undulating to gently undulating plains
Highlands	Shallow lithosols Uc 1.23	Reddish brown to yellowish brown over rock	Variable; generally shallow, rocky sandy clay loam to loamy sand; > 0.1 m to bedrock	Neutral reaction trend ; massive structure	Mountains, hills, plateaus and rises
Isaac	Loamy alluvials of no suitable group Um 5.52, Db 3.12	Brownish black to brownish grey over yellowish brown to brownish grey subsoil	Loamy fine sand to sandy clay loam surface to sandy clay subsoil; > 1.5 m	Neutral reaction trend; few inclusions or coarse fragments; often textural stratification	Level alluvial plains and levees
Jimbaroo undulating	Black earth and non-cracking clay Ug 5.12, Uf 63.2	Dark to reddish brown over dark to reddish brown subsoil	Light to medium clay over medium to medium heavy clay; < 0.45 m to bedrock	Neutral to alkaline self-mulching to hard setting surface; often stony throughout	Crests and upper slopes of rises

Kia-Ora	Black earth Ug 5.11, 5.15	Dark olive-grey to brownish black over dark brown to olive-grey subsoil	Uniform heavy clay; > 0.60 m	Fine to medium self-mulching surface over strongly structured alkaline subsoil	Undulating to gently undulating
Lascelles	As for Glengallan but sandy loam surface horizon extending 0.20 to 0.50 metres to clay subsoils				
Lonesome	Grey and brown clay Ug 5.25, 5.28, 5.15	Grey to dark grey surface in depressions, grey-brown to brown on mounds; grey to yellow-grey subsoil with prominent yellow and brown mottles	Uniform medium to heavy clay; > 1.2 m	Melonhole (> 0.4 m vertical interval) gilgai; coarse self-mulching surface in depressions, mounds often crusting and non-cracking; surface ironstone common acid to a kaline reaction trend	Gently undulating and level plains
Moramana plains	Grey, brown and red clay	Brown to red over brown, dark or red Ug 5.34, 5.24, 5.38	Medium clay over medium subsoilheavy clay; > 1.5 m	Strongly self-mulching surface over alkaline strongly structured subsoil; often forms a gilgai complex	Level alluvial
Orion	Black earth, grey clay Ug 5.12, 5.22	Grey-brown to dark throughout	Uniform medium to heavy clay; 0.45 m to 1.2 m to bedrock	Coarse to moderate self-mulching surface; neutral to alkaline; surface stone can occur; alkaline and strongly structured subsoils	Gently undulating to undulating plains and rises
Picardy	Red and brown clay Ug 5.38, 5.34, 5.24	Grey, brown, dark to red surface over similar range of subsoil colours	Light to medium heavy clay over medium to heavy clay subsoils; > 0.9 m to bedrock	Strong, fine self-mulching surface over strongly structured alkaline subsoils	Gently undulating rises to level plains
Rolleston	Grey and brown clay Ug 5.24, 5.27, 5.33	Grey to dark surface over grey to yellow-brown subsoil; red or yellow mottles at depth	Uniform medium to heavy clay; > 0.9 m	Slight (< 0.4 m vertical interval) linear or normal gilgai may occur; self-mulching surface; soil reaction trend varies from acid to alkaline	Gently undulating to undulating plains
Springton	Red and brown clay and non-cracking clay Ug 5.22, 5.37, Uf 6.31	Red to reddish brown surface over reddish brown to dark reddish brown subsoils often slightly mottled	Uniform light to medium heavy clay; > 0.6 m to bedrock	Neutral self-mulching to hard setting surface with a kaline reaction trend; often coarse structured subsoils	Undulating to gently undulating plains and rises
Turkey Creek	A kaline greyish brown duplex and solodic soil Dd 3.13, Dy 2.33, Db 3.13	Dark surface over brown, dark or grey subsoils; occasional mottling at depth	Sandy clay loam surface over medium to heavy clay; > 1.2 m	Thin (< 0.1 m) sandy hard setting surface over moderately blocky a kaline subsoils	Undulating to gently undulating plains

AMUs of the Alluvial Plains LRA

Adelong AMU consists of self-mulching, deep, dark to grey, heavy cracking clays on recent floodplains along major creek and river systems. Much of this country has been cleared of the original brigalow / coolibah scrub.

The soil has a desirable range of properties for cropping such as medium to high fertility, high to very high plant available water holding capacity (PAWC) and an effective rooting depth of more than 90 cm. Initially they have a high nitrogen content which is typical of dense scrub soils with high organic matter. Continuous cultivation without some form of trash retention usually leads to gradual nutrient decline and structural deterioration.

The major limitation is susceptibility to flooding which includes loss of access to certain areas for extended periods.

Moderately saline subsoils can occur below 80 cm depth which may marginally affect rooting depth. A sandy, crusting surface in some situations may deleteriously influence germination of crops while assisting weed seed germination.

College AMU comprises cracking and non-cracking clays on older alluvium, with one or more physical limitations of sufficient severity to prevent the success of dryland cropping in most years. Fertility is usually low. Typically, vegetation is mixed, open brigalow scrub with poplar box, bauhinia, Dawson gum and associated species.

Two broad situations exist:

- very coarsely self-mulching and crusting cracking clay, over hard and dense heavy clay subsoils which are poorly drained, strongly sodic and often saline to within 30 cm of the surface. They are usually acid by 80 to 90 cm depth which leads to aluminium in the soil becoming soluble and toxic to plants. The net result is severely restricted water availability despite the deep profile.
- non-cracking clay with hard setting surfaces. A high level of fine sand predisposes the soil surface to set hard and seal. Subsoils are very hard and impermeable. Infiltration and PAWC are reduced, as is the capacity of roots to exploit the soil. Often soil depth is restricted by gravel layers less than 60 cm from the surface.

Moramana differs from Adelong AMU because of a deeper, finer surface mulch. The soils are generally associated with natural drainage lines of open coolibah woodlands within a basalt landscape.

They are usually lower in fertility than Adelong: low phosphorous levels for cropping are common. A feature of the soils is a well drained profile and slightly less PAWC than the Adelong AMU.

Isaac AMU includes sandy loams, loams and deep, sandy surface, duplex soils on alluvium with tall grassy woodlands of blue gum and Moreton Bay ash. They are freely drained with deep effective rooting but with a reduced water storage potential because of their sandy nature. A typical feature of deep sandy soils is the effective use by plants of light rainfall.

Phosphorus levels are normally medium to high but nitrogen is very low.

Dooruna AMU comprises clay plains believed to have formed from the deposition of deeply weathered Tertiary sediments over 2 million years ago. The soils have similar features to College AMU but with markedly different landforms of flat, open plains of grasslands with sporadic clumps of stunted brigalow. The main area where this AMU is found is north-west of Kilcummin.

Soils are coarse, self-mulching, deep, grey clays characterised by hard blocky subsoils. They are strongly sodic and saline between 30 to 60 cm from the surface with acid subsoils. Effective rooting depth is severely reduced by a combination of these factors.

Attempts at cropping have resulted in failure due mainly to water stress, chloride toxicity (salt) and germination problems. The soils are productive cattle grazing country if stocking rates are not excessive.

AMUs of the Undulating Scrub Plains LRA

Rolleston AMU comprises deep, grey to brown, cracking clay soils originating from deeply weathered Tertiary material. Gilgais less than 40 cm deep occur throughout the area. A feature of Rolleston AMU is the variability in effective rooting depth, often within a small area, due to a salt bulge close to the surface and coarse structure in the subsoil. Such soils may have restrictive subsoil conditions within 30 cm of the surface, particularly on gilgai mounds. Average effective rooting depth is about 50 cm.

Areas have been prepared for dryland cultivation with poor results in most years. The reason is usually water stress because of restricted rooting depth. Rooting depth variations are reflected by patchy crop performance, particularly in drier areas.

These soils perform well in the Emerald Irrigation Area where water stress due to restricted rooting can be overcome with proper water management.

Fertility varies considerably and surface conditions similarly vary from sandy crusting to self-mulching. Variability of chemical and physical attributes is often compounded where areas of less productive AMUs occur in close association. Lascelles, Glengallan and Glen Idol AMUs commonly occur with Rolleston creating difficulties in managing it as a single unit.

Lonesome AMU is an extension of the Rolleston AMU where gilgais become melonholes with more than 40 cm vertical interval between mounds and depressions. The limiting factors described in Rolleston become more severe with Lonesome as the depth of melonholes increase. Added to this is the waterlogging of depressions for extended periods. Gilgai mounds contain the poorer soils with very high salinity close to the surface (less than 30 cm depth). They are often acid at depth with aluminium toxicity resulting.

Turkey Creek AMU is not widespread but the soils are significant for cropping. It is a duplex soil characterised by a thin (less than 10 cm), sandy loam to clay loam surface overlying deep, grey to brown, moderately well drained and structured, heavy clay. Vegetation is brigalow, Dawson gum, belah and yellowwood scrub. Once cultivated, it often reverts to a cracking clay with a sandy clay plough layer.

Immediately following clearing, fertility is high, However rapid decline has been observed after less than five years cultivation.

The soil is particularly prone to developing plough pans thereby reducing the movement of water through the subsoil.

Specific management techniques to preserve structure and organic matter are required on soils of the Turkey Creek AMU.

Springton AMU consists of moderately deep to deep, red to brown cracking and non-cracking clays under brigalow, Dawson gum, gidgee, bendee or bonewood scrub. The dominant characteristic is impeded drainage resulting in a reduced plant available water capacity leading to plant stress.

The reasons for water stress may be one or a combination of the following conditions:

- reduced soil depth because of gravel or parent rock often encountered between 45 to 90 cm, particularly in non-cracking soils;
- hard setting, crusting surface which restricts infiltration; and
- restricted drainage and effective rooting depth due to coarse-structured clay subsoils. This common feature of Springton AMU probably results from the combined effects of high levels of fine sand and sodium-induced clay dispersion. These affect the pore space and therefore the aeration and hydraulic conductivity of the subsoil.

Cultivation often produces a fine seedbed with a high germination potential only to be followed by disappointing growth due to water stress. Waterlogged surface soils can overlie hard, dry subsoils following heavy rain. Runoff losses are high in such instances.

A lower clay content enables better PAWC because less moisture is tied up in the clay matrix. For this reason Springton AMU can often maintain effective plant production in times of frequent, short duration storm rains.

Soil fertility varies from low to medium with nutrient depletion occurring after cultivation. Moderate salinity at depth is normally a secondary limiting factor to reduced plant available water capacity and effective rooting depth.

Picardy AMU represents the deep, fertile, red, brown and grey cracking clay scrub soils which occur extensively throughout the region. Apart from high fertility, they have physical attributes conducive to high PAWC and an effective rooting depth greater than 90 cm.

The major limiting factors for Picardy AMU are slopes susceptible to erosion. Areas of shallow gilgai are also common.

Glengallan AMU consists of duplex soils characterised by a thin, hard setting sandy loam to sandy clay loam surface over very coarsely structured, impermeable and sodic clay subsoils. Often a bleach occurs at the base of the topsoil which is indicative of extended waterlogging in that part of the soil profile.

On these soils, the sandy upper layer represents the major opportunity for root exploration.

Apart from severely limiting physical conditions, the soils are also very low in nutrients with little to no potential for improvement. Using gypsum as a soil structural ameliorant is uneconomic for dryland cropping. Its effects are usually temporary and minor to non-existent. The soils are very prone to plough pan development.

The sodic and highly erodible subsoil should not be exposed under any circumstances.

Glen Idol AMU is commonly associated with Duckponds and Springton AMUs. Soil depth is moderate to deep (more than 90 cm), with a red to brown sandy clay loam surface usually less than 30 cm deep overlying a clay subsoil. The soils are moderately well structured and drained although restrictions to root and water penetration, due to coarse soil structure, are usually apparent by a depth of 70 to 80 cm. PAWC and fertility are medium although high phosphorus levels occur in certain areas (eg. Arcadia Valley).

Original vegetation includes brigalow / eucalypt scrub with associated ooline, bonewood or gidgee. Much of this AMU has been cleared for grazing.

The major limitation is insufficient water availability for cropping in most years because of a sealing surface and the imperfect subsoil conditions outlined above. Moderately saline subsoils can also contribute to an insufficient water availability.

AMUs of the Eucalypt Duplex Plains LRA

Lascelles AMU varies from Glengallan only in the depth of the sandy surface horizon and its associated vegetation. It possesses all the physical limitations of Glengallan AMU, but it has an improved rooting zone of 20 to 50 cm with additional PAWC. Some very minor improvement in long-term productivity potential exists.

Like Glengallan AMU, exposure of the sodic and highly erodible subsoil should be avoided.

AMUs of the Undulating Downs LRA

Orion and Jimbaroo AMUs are the black to dark reddish brown, heavy, cracking clay soils formed on Tertiary basalt. Both AMUs contain areas of surface stone. They have been grouped on the depth to weathered or fresh parent rock.

Orion AMU has a soil depth greater than 45 cm and an average of 60 to 80 cm. Deeply weathered (to more than 1.2 m) basaltic soils on which scrub has developed are included in Picardy AMU.

A thin (approximately 2mm) blocky mulch overlies highly structured heavy clay with high PAWC, the amount of which is directly proportional to soil depth. Roots can extensively exploit the well-structured soil.

Surface nitrogen and phosphorus levels are normally medium. Nutrient depletion problems become apparent on some older areas of cultivation. An indication of this problem can be obtained from organic carbon, nitrogen and phosphorus analysis.

The coarse self-mulch creates problems for establishing fine seeded pasture species because of the poor soil - seed contact.

Jimbaroo AMU has a depth of soil less than 45 cm. The probability of water stressed crops increases significantly with soil depth shallower than this. The shallower ‘downs’ soils are often associated with steeper and erosion-prone landscape positions. Shallow (less than 45 cm) non-cracking red, brown and dark clays are included in Jimbaroo.

Kia-Ora AMU are black to dark olive-grey heavy clays formed on fine-grained sedimentary shales and mudstones. They form a unique group and are concentrated mainly to the south-west of the Central Highlands.

Soils typically have a deeper (about 5 mm) granular mulch than Orion AMU. This often forms a weak sandy crust. The soils also have a generally greater depth to bedrock (90 to 140 cm) than Orion.

Well-structured and drained subsoils can be extensively exploited by roots.

The PAWC is high to very high.

Surface fertility is medium to high with often very high phosphorus levels.

AMUs of the Plateaus LRA

Duckponds AMU is the deep red and yellow earths and duplex soils with a deep A horizon associated with plateaus, relict fans and ridges of undulating plains.

The essential feature of this AMU is a deep (more than 45 cm), freely drained, sandy upper horizon. Water storage potential is low because of low clay content but PAWC can be low to medium. This can be compensated to a certain extent, however, by the overall depth of the sandy material where water can be retained and immediately available for root uptake.

Such soils have the capacity to retain moisture from light rainfall or short rainfall events for plant use. Nonetheless, longer term storage potential is the major limitation.

Fertility is typically low as is salinity and sodicity and quartz gravel layers are common.

AMUs of the Ranges LRA

Highlands AMU represents a large portion of the area and comprises a variety of shallow, skeletal and sandy soils associated with dissected landscapes.

The soils have common features which are very low fertility and massive surface structure. This greatly restricts land use potential.

Table 5.3. *Summary of chemical characteristics of AMUs*

AMU	Surface pH	Total N	Extractable Phosphorous		Extractable			Average Salinity	Sodicity
			Acid	Bicarbonate	Potassium	Copper	Zinc		
Adelong	7.0 to 8.5	low to medium	medium to very high	low to high	very high	medium	medium	low	sodic below 1.2 m
College	7.5	low to very low	very low	very low	medium	medium	low	high	strongly sodic below 0.3 to 0.5 m
Dooruna	7.0	very low	very low	very low	very low	medium	low	high	sodic below 0.3 to 0.5 m
Duckponds	5.0	very low	low	very low	medium to high	medium	low	very low	non sodic
Glengallan	6.5	very low	low to medium	low	medium	medium	low	low	strongly sodic below 0.2 to 0.3 m
Glen Idol	7.0	low	low to high	low to high	medium	medium	low	low	non sodic
Highlands	6.5	very low	very low	very low	very low	medium	low	very low	non sodic
Isaac	6.5	very low	high	high	medium	medium	medium	very low	non sodic
Jimbaroo	7.0 to 8.5	low to medium	low to medium	low	high	medium	low	very low	non sodic
Kia-Ora	8.0	low to medium	very high	very high to medium	high	medium	low	very low	non sodic
Lascelles	6.5	very low	very low to medium	low to very low	medium	low to medium	low	low	strongly sodic below 0.4 to 0.6 m
Lonesome	8.0	low	low	low	medium to high	medium	low	high	strongly sodic below 0.2 m (mounds) or 0.6 m (depressions)
Moramana	7.5	low	low	very low	medium	medium	low	very low	non sodic
Orion	7.5	low	very low	low	medium to high	medium	low	very low	non sodic
Picardy	7.5 to 8.5	medium	medium to high	medium to high	medium to high high	medium to	low	very low below 1.2 m	may be sodic
Rolleston	8.0	very low to medium	very low to medium	very low to medium	high	medium	low	very low to medium	sodic below 0.5 to 0.9 m
Springton	8.0 to 8.5	low to medium	low to medium	low to medium	medium	medium	low medium	low to below 0.5 to 0.9 m	strongly sodic
Turkey Creek	8.0	low to medium	low to medium	very low to low	medium	low	low	low	sodic below 0.70 m

Table 5.4. *Summary of physical characteristics of AMUs*

AMU	Effective Rooting Depth	Limiting Factors to Effective Rooting Depth	Surface Condition	PAWC
Adelong	greater than 1.0 m	occasional salt bulge below 1.0 m	strong coarse self-mulch 2 to 4 mm thick	high to very high
College	0.2 to 0.4 m	coarse sodic structure, salt bulge or gravel	coarse self-mulch, hard setting or crusting	low
Dooruna	0.3 to 0.6 m	salt bulge and coarse sodic structure	very coarse self-mulch	low
Duckponds	1.0 m	gravel layers or coarse clay subsoil	loose or firm to hard setting	low to medium
Glengallan	less than 0.2 m	coarse sodic clay	hard setting	very low
Glen Idol	0.5 to 0.8 m	hard clay subsoils or gravel	firm to hard setting	medium
Highlands	less than 0.3 m	soil depth to rock	firm to hard setting	very low
Isaac	greater than 1.0 m	occasional alluvial gravel or clay layering	loose to firm	low to medium
Jimbaroo	less than 0.45 m	soil depth to rock	strong medium self-mulch approx. 2 mm thick	low to medium
Kia-Ora	greater than 0.45 m (average 0.9 m)	depth to bedrock	strong fine self-mulch 3 to 5 mm thick	high to very high
Lascelles	0.2 to 0.5 m	hard sodic clay subsoils	hard setting	very low to low
Lonesome	0.2 to 0.6 m	salt bulge or acid pH or sodic clay	crusting, coarse self-mulch	medium
Moramana	greater than 1.0 m	--	strong fine self-mulch 3 to 5 mm thick	high
Orion	0.45 to 1.2 m	depth to bedrock	strong medium self-mulch 2 mm thick	high
Picardy	greater than 0.9 m	occasional salt at depth	strong granular fine self-mulch 2.5 mm	high to very high
Rolleston	0.5	hard sodic clay subsoils, salt bulge or acidic pH	sandy crusting to self-mulching	medium to high
Springton	0.45 to 1.0 m	hard coarse subsoils, gravel or parent rock	firm to hard setting surface or surface crust	low to medium
Turkey Creek	0.6 to greater than 1.0 m	hard coarse subsoils or gravel. Occasionally salt bulge	firm to hard setting, sandy	medium to high

Agricultural land management 6

Introduction

This section defines the suitability of the AMUs for crop and pasture production and the management requirements for optimum productivity. Limitations for agricultural management for each AMU are listed in the 'Summary Sheets' in the *Field Manual*.

Grain and fodder cropping

A broad range of crops is grown in the district (Table 6.1). The main dryland crops are sorghum, sunflower and wheat, while in the Emerald Irrigation Area the main crop is cotton.

Table 6.1. *Crop type by season and farming method*

	Dryland	Irrigated
Winter	Wheat Chickpea Safflower	Wheat Chickpea
Summer	Sorghum Sunflower Mungbeans Cotton	Cotton Sorghum Sunflower Peanuts Maize Soybeans

The main fodder crops are the forage sorghums in summer and oats in winter with minor areas of dolichos. Lucerne is also grown under irrigation.

The suitability of the AMUs for dryland grain and fodder crops is presented in Table 6.2.

Strictly planned rotations are not common in the Central Highlands. The variability of the rainfall and its timing prevents fixed rotations. The crop type selection is based as much on economic returns as on planting opportunity. However, farmers avoid growing the same crop in the same paddock for more than 3 to 5 years in a row. This attempts to reduce weed, disease and insect problems, improve soil structure, or reduce vulnerability to soil erosion.

Fallow lengths range from very short (1 to 5 months) for opportunity cropping (where a spring crop may follow a summer crop or a summer crop follow a winter crop), to long (10 to 11 months) when changing from sorghum to wheat. Generally, fallow lengths are about six months where the same crop is planted in the same paddock. Fallow periods can be longer if insufficient rainfall delays planting opportunities.

Table 6.2. *Suitability of Central Highlands AMUs for the major dryland grain and fodder crops*

AMU by LRA	Grain crops Sorghum	Sunflower	Wheat	Chickpea	Forage sorghum	Oats
Alluvial Plains						
Adelong	S	S	S	S	S	S
College	NS	NS	NS	NS	LS	NS
Dooruna	NS	NS	NS	NS	NS	NS
Isaac	NS	NS	NS	NS	NS	NS
Moramana	S	S	S	S	S	S
Undulating Scrub Plains						
Glengallan	NS	NS	NS	NS	S	S
Glen Idol	NS	NS	LS	LS	NS	LS
Lonesome	NS	NS	NS	NS	NS	NS
Picardy	S	S	S	S	S	S
Rolleston	LS	NS	LS	LS	S	S
Springton	NS	NS	NS	NS	S	S
Turkey Creek	S	S	S	S	S	S
Eucalypt Duplex Plains						
Lascelles	NS	NS	NS	NS	NS	NS
Undulating Downs						
Jimbaroo	NS	NS	NS	NS	NS	NS
Kia-Ora	S	S	S	S	S	S
Orion	S	S	S	S	S	S
Plateaus						
Duckponds	NS	NS	NS	NS	LS	NS
Ranges						
Highlands	NS	NS	NS	NS	NS	NS

S = Suitable. No or minor limitations to the growing of the crop.

LS = Limited Suitability. Severe limitations mean the crop can not be regularly grown, only when conditions are favourable.

NS = Not Suitable. Extreme limitations preclude crop growth.

Soil limitations and management

A summary of the major characteristics of the AMUs which may limit production is presented in Table 6.3, and a discussion of the management of these productivity limitations follows.

Table 6.3. *Summary of major soil related factors of the AMUs which may be limiting to production in the Central Highlands*

LRA/AMU	No.	Effective rooting depth (m)	PAWC[1]	Soil nutrient status	Salinity/ Sodicity[2]	Surface characteristics[3]	Erodibility	Pasture establishmment	Regrowth
Alluvial Plains									
Adelong	(1)	1.0	high to very high	high	both (deep)	fine mulch	high	easy	severe
College	(2)	0.2 to 0.4	low	low	both	hard setting/mulching	low	difficult	moderate
Dooruna	(3)	0.3 to 0.6	low	very low	both	coarse mulch	low	extremely difficult	low
Isaac	(8)	1.0	low to medium	low N; high P	neither	structureless	low	difficult	moderate
Moramana	(13)	1.0	high	low to moderate	neither	fine mulch	moderate	very difficult	low
Undulating Scrub Plains									
Glengallan	(5)	< 0.2	very low	very low N	sodic	hard setting	low	easy	severe
Glen Idol	(6)	0.5 to 0.8	medium	low to medium	saline	firm to hard setting	very high	easy	severe
Lonesome	(12)	0.2 to 0.6	medium	low to medium	both	thin crust (gilgai)	low	difficult	severe
Picardy	(15)	0.9	high to very high	medium to high	both (deep)	fine mulch	high	easy	severe
Rolleston	(16)	0.5	medium to high	very low to medium	both	coarse crust	moderate	dificult	severe
Springton	(17)	0.45 to 1.0	low to medium	low to medium	both	hard setting	high	easy	severe
Turkey Creek	(18)	0.6 to > 1.0	medium to high	medium	both	hard setting	high	easy	severe
Eucalypt Duplex Plains									
Lascelles	(11)	0.2 to 0.5	low to very low	very low	sodic	hard setting	very high	difficult	severe
Undulating Downs									
Jimbaroo	(9)	0.45	low to medium	low to medium	neither	coarse mulch	very high	extremely difficult	low
Kia-Ora	(10)	> 0.45	very high to high	medium to high	neither	fine mulch	very high	difficult	low
Orion	(14)	0.45 to 1.2	high	low	neither	coarse mulch	very high	extremely difficult	low
Plateaus									
Duckponds	(4)	1.0	low to medium	very low N; low P	neither	sandy to hard seting	low	easy	moderate to severe
Ranges									
Highlands	(7)	< 0.3	very low	very low	neither	firm to hard setting	high	extremely difficult	severe

[1] PAWC - is estimated to effective depth of wetting

[2] Salinity/Sodicity at depth (generally below 30 cm)

[3] Surface Characteristics - only those characteristics which affect crop production or establishment are noted.

Water Erosion

All cultivated land in the Central Highlands is subject to water erosion to varying degrees. The extent of the problem is governed by:

- erodibility of the soil;
- slope of the land;
- length of the slope;
- soil cover and roughness;
- storm intensity and duration; and
- antecedent moisture (moisture in the soil before the storm event).

Soil erosion reduces productivity more on shallow soils than on the deep soils. The control of erosion on the shallower cropping soils is therefore vital to maintaining economic production.

A combination of structural and agronomic measures is necessary to control water erosion. The use of these erosion control measures is discussed in Section 7. For cultivated soils, as the land slope increases so too does the erosion hazard. This increased erosion hazard determines:

- the level of structural measures required (eg. contour banks, waterways);
- the type of stubble management practices recommended; and
- the number of suitable cropping options available.

Erosive flooding can occur on the alluvial soils beside major streams. The best of these soils are farmed and are therefore more at risk from this type of erosion.

Soil structural decline

Nearly all the arable soils in the Central Highlands are self-mulching (a self-generating crumbly clay soil surface), so surface structure decline is a minor problem in these soils. However, evidence from research into 'no-till' techniques shows that the size of the stable aggregate (the ped, or natural lump) increases to approach that existing in the uncultivated state. Thus, some structural changes do occur in the district's cracking clay soils due to cultivation.

Structural damage

Wet clay soils have very low strength and can be readily compacted and sheared (smeared and sealed) by using heavy machinery or tilling soil when it is too wet. Damage can result from one, or a combination of the following three processes:

Compaction - soil is compressed; all of the large pore spaces are destroyed thus reducing infiltration capacity, water conductivity and soil aeration. This makes conditions unfavourable for root growth.

Remoulding - the character of the soil is changed leaving a disturbed soil structure with few pores, and poor infiltration and aeration creating unfavourable rooting conditions. This happens when the soil is too wet for working.

Smearing - remoulding creating a smooth surface occurs with the resulting smeared surface being impermeable to water.

Damage to soil structure by trafficking or tillage when the soil is wet produces one or a combination of:

- cloddy seedbeds;
- platy or massive dense layers in the soil; and
- smeared layers from tillage tools.

These effects on soil structure often show up as one or more of the following symptoms in the plants:

- L-shaped or stumpy roots;
- yellow (waterlogged) plants after rain or irrigation;
- small, stunted plants; or
- thirsty plants requiring frequent irrigation.

Cracking clay soils can partially recover from structural damage by themselves as the soil dries out and cracks. The compacted layers are disrupted by deep cracks on drying, and the blocks shatter when tilled. It is necessary to dry out the soil layers below 10 cm by growing a crop, provided the crop roots can penetrate below the compacted layer. If the crop has a ‘dry finish’ and successfully dries out the deeper soil layers, subsequent tillage will shatter the compacted layer.

To prevent structural damage on cracking clay soils:

- traffic and till when they are not too wet. To tell if soil is too wet, take a handful of soil and knead it into a golf ball sized sphere using firm pressure. Roll out a 3 mm diameter rod of this soil on a flat surface. If the soil crumbles before a 3 mm rod forms, then the soil is safe to till.

  If a 3 mm or less rod forms, then the soil is too wet and needs to dry further before tillage occurs, or if further drying is not possible, then keep tillage to a minimum. ***Note: This test must be done with separate samples down the soil profile to below the depth of tillage.***

- minimise tillage;
- control weeds with herbicides; and
- apply fertiliser by banding into hills when soil is relatively dry.

Where structural damage is inevitable, an alternative management approach is to contain the area of impact by retaining hills and 'tramlining' (i.e. using the same wheel tracks on each pass). This restricts traffic to semipermanent areas and, combined with minimum tillage practices, permits maintenance of good soil structure in the area between the tramlines.

In irrigation areas this is being done to some extent. The worst compaction usually occurs in dryland situations. This is because up to 75% of the area can be covered by wheel tracks of some sort in the life of the crop.

Some of the marginally arable AMUs like Glen Idol, Glengallan, Rolleston, College, Isaac and Duckponds do set hard when they are cultivated. Tined implements should be used in preference to disc implements on these soils, particularly to reduce pulverisation of the surface soil and reduce the development of a hard setting surface.

Plant Available Water Capacity (PAWC)

PAWC varies from very low to very high for the AMUs of the district. It may be low because of soil depth (e.g. Jimbaroo AMU); soil type (e.g. Lascelles and Duckponds AMUs) or high salinity close to the surface (e.g. Dooruna and College AMUs).

All arable AMUs in the district have medium to very high PAWC. It is probably the most important factor in deciding if a soil is arable.

A soil that has a high PAWC may still have problems with acquiring moisture, infiltration and wetting-up the profile. Therefore special management practices are required to increase infiltration and reduce evaporation, so that high PAWC soils can be used to their potential. These practices are:

- maintain maximum amounts of crop residue for as long as possible in the summer. Standing crop residues are more effective than stubble which lies on the surface;
- maintain a rough surface condition and contour cultivate to improve surface storage;
- use reduced tillage techniques using only tined implements and possible herbicide substitution; and
- deep rip soils with hardpan development.

Effective rooting depth

Within the cracking clay AMUs, a 50 cm effective rooting depth is regarded as the soil depth separating marginal or non-arable soils from arable ones. Hence, even though Jimbaroo and Orion are a similar soil, they are different AMUs as Jimbaroo is considered too shallow for permanent cultivation, being less than 50 cm deep.

With Duckponds and Lascelles AMUs, for example, while the soil profile is deep, the effective rooting depth may only be the depth of the A horizon due to the impermeable nature of the subsoil.

Highlands AMU is also a shallow soil, generally too shallow for any form of development.

Soil nutrient status

Soil nutrient status of the arable AMUs depends on:

- original vegetation;
- length of time farmed and history of use; and
- geographic location.

Soil fertility of the Central Highlands soils is generally low, regardless of age of cultivation or improved pasture development. Despite this low fertility, fertilisers are still not used extensively, even though their use is recommended, particularly on old cultivation in Orion AMU. Crop and pasture yields are more often limited by shortage of soil water than by a shortage of nutrients.

Soil salinity and sodicity

Soil salinity and sodicity are a characteristic of the deeply weathered Tertiary sediments which underlie a lot of soils in the district. Dooruna and College AMUs for example, are saline and sodic enough to preclude dryland cropping if no other restrictions are operating. These Tertiary deeply weathered clays also underlie Rolleston and Lonesome, hence these AMUs may also be saline and, or sodic.

On the basalt AMUs (Orion and Jimbaroo) rising water tables because of overclearing, particularly of black tea tree in drainage lines, can lead to surface salting.

Summary

The better AMUs for grain cropping, in decreasing order, are Picardy, Turkey Creek, Adelong, Kia-Ora, Moramana and Orion. The AMUs considered marginal for cropping are Rolleston, Glengallan, Springton and Glen Idol. While all the above mentioned AMUs are suitable for forage cropping, the marginal AMUs are generally the ones most used in this way.

Pastures

Native pastures

The predominant native grasses are Queensland bluegrass (*Dichanthium sericeum*), desert bluegrass (*Bothriochloa ewartiana*), pitted bluegrass (*B. decipiens*), black speargrass (*Heteropogon contortus*), kangaroo grass (*Themeda triandra*), spinifex (*Triodia mitchellii*), barley grass (*Panicum decompositum*), yabila grass (*P. queenslandicum*), white speargrass (*Aristida leptopoda*), mitchell grasses (*Astrebla* spp.) and flinders grasses (*Iseilema* spp).

With light grazing, the grasses of the Undulating Downs LRA provide good grazing during summer but not much nutrition during winter. Poor management of these native pastures will mean an increase in less palatable species like white speargrass and yabila grass. Red Natal grass (*Melinis repens*) also invades degenerate pastures on lighter soils.

All AMUs produce native pastures from the productive Orion and Kia-Ora through Lascelles and Duckponds to the poorest Highlands and virgin scrub AMUs.

Timber treatment is the main method graziers use to increase native pasture production. Chemical injection is the recommended method to reduce the number of mature trees, as mechanised methods lead to severe regrowth problems. The AMUs suitable for this are Duckponds, Lascelles, Isaac, Moramana, Jimbaroo and College.

Seca stylo (*Stylosanthes scabra*) grows in the lighter textured soils found in the Duckponds, Lascelles and Isaac AMUs. However, unless the phosphorus levels are greater than 10 ppm the legume will make no contribution to animal production. Phosphorus supplementation through drinking water or licks means that seca additives to the above AMUs will be beneficial.

Once Dooruna AMU has been cultivated, recolonisation by native pastures is difficult.

Introduced pastures

Pasture improvement is used extensively throughout the district. Soil characteristics influence both establishment and productivity. Other factors such as adverse weather conditions, regrowth control, seedbed conditions, soil fertility and management practices all contribute to the variable success of introduced pastures.

The major pastures used in the district are buffel grass, rhodes grass, green panic and purple pigeon grass. Buffel grass is the main grass used in the scrub AMUs, as well as Kia-Ora, Lascelles, Isaac and Duckponds AMUs. Green panic is used only in the south of the district as weather conditions do not generally suit it elsewhere. The small-seeded pastures do not establish very well on the coarse self-mulching clay soils of Orion or Jimbaroo AMUs. Purple pigeon grass is more appropriate for these soils.

Pasture establishment is extremely difficult in the Dooruna AMU because of the extremely coarse surface mulch, low phosphorus levels and high salinity.

Production from improved pastures on Glengallan and Lascelles AMUs for example, will be low because of low PAWC.

Many established buffel grass pastures are declining in productivity due to decreasing soil nitrogen levels. There is no legume to add to these pastures on the heavy clay soils, hence the only treatment appears to be a mechanical renovation associated with sucker control.

Recommended pasture species for the AMUs are given in Table 6.4.

Table 6.4. *Recommended species for pasture plantings on AMUs in the Central Highlands*

AMU	Buffel grass	Green panic	Rhodes grass	Creeping bluegrass	Purple pigeon	Silk sorghum	Lucerne	Seca stylo
Adelong	✓	✓	-	✓	✓	✓	-	-
College	✓	-	✓	-	✓	✓	-	-
Dooruna	-	-	-	-	-	-	-	-
Duckponds	✓	-	✓	-	-	✓	-	✓
Glen Idol	✓	✓	✓	-	-	✓	-	✓
Glengallan	✓	✓	✓	-	-	✓	-	✓
Highlands	-	-	-	-	-	-	-	-
Isaac	✓	✓	-	-	-	-	✓	✓
Jimbaroo	-	-	-	✓	✓	✓	-	-
Kia-Ora	✓	-	-	✓	✓	✓	-	-
Lascelles	✓	-	✓	-	-	✓	-	✓
Lonesome	✓	-	✓	-	✓	-	-	-
Moramana	-	-	-	✓	✓	✓	-	-
Orion	-	-	-	✓	✓	✓	-	-
Picardy	✓	✓	-	✓	✓	✓	-	-
Rolleston	✓	-	✓	✓	✓	✓	-	-
Springton	✓	✓	-	✓	✓	✓	-	-
Turkey Creek	✓	✓	✓	✓	✓	✓	-	-

Ponded pastures make use of stored water to grow para grass (*Brachiaria mutica*), aleman grass (*Echinochloa polystochya*) and hymenachne (*Hymenachne amplexicaulis*). More erratic rainfall and the lack of suitable sites are not as conducive to the widespread adoption of the practice as in the coastal area. Ponded pastures in the Central Highlands districts do work however, and are increasing in popularity.

Grazing management

To maintain pastures in good condition, only 30% of the available feed should be used.

While this apparent low use appears to 'waste feed', it allows grasses to remain vigorous and seed, while dry, old leaves provide fuel for burning. If a pasture is neither grazed nor burnt for several years there is little nutrient recycling and the pasture will become depleted and lacking in vigour. High utilisation may seem more profitable in the short-term but it will degrade any pasture. Perennial species are eaten out, the area of bare soil then increases and weeds will invade.

The basic rule of managing grazing for the sustainability of the pastures is to give the best species a chance to recover from grazing and to set seed.

As the best species are going to be grazed the most, they need to be given a chance by:

- using a stocking rate that does not put them under undue pressure; and
- spelling periodically when they are flowering and seeding.

This will usually happen if the paddocks are grazed so that they *could* carry a fire (even if a fire is not part of the immediate management).

Fire does not damage most pasture species (except, possibly, seca stylo). It is the animals grazing the new growth and seedlings after the fire that do the damage.

In the Central Highlands the developed scrub country should be burnt every 3 to 5 years and the forest country every 2 to 4 years. Of course, all this is season dependent.

In the Central Highlands, drought should be considered as part of any overall management strategy and planned for in a systematic manner with a pre-determined response. Most damage to pastures is done when stock numbers have not been reduced in droughts. The critical period is immediately after the drought breaks.

The aims of a drought management strategy should be to:

- maintain long term viability of the property;
- prevent degradation of land and pasture; and
- provide sufficient cash flow for short-term needs.

Seasonal mating, with pregnancy diagnosis and early weaning, are some of the basic strategies for evading the worst effect of drought.

Seasonal mating can prevent calves being born at the wrong time e.g. in autumn when the cows do not produce milk because feed is low. Cows with calves are always some of the first to die, after they have helped to put pressure on the pastures.

Pregnancy diagnosis identifies cows that are not pregnant six months earlier than waiting to see if a calf drops. These animals can be culled for cash and will also save grass.

If the summer season has been dry up to March, any rain after that time should be regarded as an unreliable bonus. It should not be planned on. Stock numbers should always be reduced before the paddocks become bare.

Land types

A related system, to that of the Land Management Manuals, has previously been developed for management purposes in grazing country. This system groups areas of land that support similar vegetation. These areas of land are regarded as good indicators of production potential and are called *land types*. The information is provided in *Property development guidelines for the Central Highlands,* Bourne, 1986.

Although the classified units are derived differently for each system, the land type sheets developed for the Central Highlands are linked to the AMUs discussed in this manual. Either system may be used depending on the detail of information required.

The relationship between the two systems is given in Table 6.5.

Table 6.5. *Relationship between land types and AMUs of the Central Highlands*

** Land Type	AMU	LRA
Downs and Open Woodland	Orion Jimbaroo Kia-Ora * Dooruna	Undulating Downs * Alluvial Plains
Brigalow-Softwood Scrub	Adelong Picardy Turkey Creek Springton Glen Idol	Undulating Scrub Plains
Brigalow-Eucalypt Scrub	Adelong Rolleston Lonesome Glengallan Glen Idol Turkey Creek Duckponds College	Undulating Scrub Plains
Gidgee Scrub	Picardy Glen Idol Springton	Undulating Scrub Plains
Flooded Coolibah	Moramana * Isaac	Alluvial Plains
Eucalypt Woodland plus shrubby understorey	Lascelles Glengallan Duckponds	Eucalypt Duplex Plains Plateaus
Eucalypt Woodland minus shrubby understorey	Duckponds Glen Idol Lascelles	Eucalypt Duplex Plains Plateaus
Lancewood - Bendee - Rosewood Scrub	Highlands Lascelles Glen Idol	Ranges

* Not a good fit
** From Bourne (1986)

Clearing strategies

Property planning

Nearly all of the country suitable for development as cultivation or improved pastures has been cleared, but not necessarily appropriately. The major area of potential development is the forest country (predominantly in the far west of the area) where a reduction in the number of trees will lead to increased production from the native pasture. Where clearing has not occurred, the following principles should be considered when preparing a property development plan to avoid unwise clearing that could lead to land degradation.

- Prepare a map of the area to be cleared. A whole property map is preferable to show the area to be cleared in relation to the whole property. The map should identify AMUs (or land types), major ridges and drainage lines, existing improvements and areas requiring special treatment.
- Suitable land use can be planned by identifying the areas to be cleared for cropping or pastures in relation to the distribution of suitable AMUs as recommended in Tables 6.2 and 6.4.
- Shelter belts and clumps (belts a minimum of 100 m wide and clumps 2 to 5 ha) should be incorporated in the plan. These can function as wildlife corridors when properly laid out and coordinated with neighbouring properties. They also act as shelter for stock and assist in stock movement when laid out correctly.
- Areas that are to be left (e.g. shelter belts) must be worked out prior to clearing. It takes time and effort but is well worth it.

Timber clearing guidelines

The following guidelines on what and where to clear have been jointly developed between officers of the Department of Lands, Department of Environment and Heritage and Department of Primary Industries.

Areas *unsuitable* for clearing:

- areas that are too steep. In the Central Highlands this is land > 20% slope;
- within 200 m either side of major watercourses;
- within 100 m either side of creeks;

- within 50 m either side of minor creeks and gullies;
- areas where the erosion hazard is severe and would be worsened by clearing;
- areas with a high salting risk;
- intake areas for underground water;
- areas that contain commercial timber (milling);
- areas that contain valuable yard / fencing timber like rosewood, lancewood, or bendee;
- areas that have important conservation value; and
- gazetted roads.

In areas *suitable* for clearing:

- retain about 20% in strips greater than 100 m wide for shade, shelter, windbreaks, wildlife corridors, fauna habitat, firebreaks and future selected timber / posts resource; this 20% can include some of the areas already set aside (e.g. 100 m either side of creeks);
- shade clumps need to be 2 to 5 ha to be a sustainable area;
- interconnect 100 m wide timbered strips to water courses and other retained woodland areas; and
- do not have 20% retention as scattered trees (particularly in forest areas) because of seedling regrowth problems and wildlife habitat fragmentation.

Clearing techniques

Initial clearing is only the first step in the process of developing land for farming or pastures. Management should incorporate strategies to deal with the subsequent regrowth problems that inevitably arise. Effective means for clearing and managing regrowth without causing further degradation are discussed in the following sections.

Clearing can involve mechanical or chemical means.

Several important points need to be considered when clearing and developing timbered country.

- develop the best soil first. These soils have the highest productivity and will provide the fastest return on the development dollar;

- clear only what can be handled efficiently, giving consideration to the time, effort and expense that may later be required for regrowth control;
- timing of the clearing operation is of prime importance. Optimum timing is dependent on seasonal conditions, the type of timber and likely regrowth problems. The general rule of clearing is 'the wetter the better'. When soil is wet, trees are removed roots and all, resulting in less suckering. This complete removal of trees also saves the cost of de-stumping before cultivation;
- if clearing must be carried out when conditions are unfavourable, areas most likely to sucker should be avoided. Areas containing sandalwood, whipstick and immature brigalow are examples of those which should be avoided. Areas of softwood scrub and associated species will have fewer regrowth problems when cleared under poor conditions;
- in brigalow, gidgee and associated scrub areas, most clearing is carried out by pulling. A chain is pulled along between two large bulldozers. The chain should be heavy enough to stay at ground level. In brigalow-eucalypt areas, the addition of a wire rope that rides up the trunks of trees may be needed to provide more leverage to pull down the larger eucalypt trees;
- eucalypt woodland and coolibah areas are usually cleared by treepushing with a bulldozer. Problems of trees snapping off and germination of seedlings caused by ground disturbance are common with this technique. A better alternative in these areas is chemical tree control; and
- pulled timber can be burnt before or after stickraking, depending on the density of timber and the quantity of dry grass present. On sloping country, timber should be windrowed on the contour to reduce soil erosion problems.

Regrowth control

Landholders must be conscious of potential regrowth problems when developing new areas. Regrowth control is generally more expensive than the initial clearing.

The main aim when controlling regrowth should be to replace the woody plants with forage species. These will reduce the likelihood of re-establishment of woody plants from seed, as well as increasing production levels.

There are three key considerations in regrowth control.

- early recognition of the problem. Chemical or mechanical control is more effective when woody weeds are 0.2 m high compared with 2 m high. Unfortunately, control is usually left until woody weeds are large;
- maintenance of a vigorous summer pasture. This will reduce establishment from seed and the growth rate of woody weed seedlings, and enable burning of untreated regrowth in the first two years of regrowth establishment; and
- dry summers and wet autumns are ideal for woody weed establishment. Another consequence of dry summers is that they produce insufficient fuel for good regrowth control through burning.

The main regrowth control methods used are:

- re-pulling - when regrowth is greater than 5 m high, simply sets regrowth back;
- chaining - often done in two directions, a quick and cheap operation but only sets suckers back;
- fire - kills very few species directly but sets back regrowth and encourages native and introduced grasses to spread;
- stickraking - generally only sets regrowth back a season or two, and subsequent treatment, farming or blade ploughing, for example, is still required;
- ploughing - controls almost all woody weeds with only one deep working, and is best achieved with heavy duty blade-ploughs; and
- chemicals - available for overall spraying, basal bark treatment, cut stump treatment, stem injection and soil treatment.

The applicability of these methods depends on many factors, such as the type of timber, stage of regrowth and future use of the land. For more specific information, see the 'Further Reading' section in this manual or seek advice from DPI officers.

Noxious weeds

Poor summer grass competition, resulting either from dry summers or high stocking pressures combined with wet autumns and winters, is ideal for the germination and spread of noxious weeds such as prickly acacia, rubber vine, chinee apple, parthenium and others.

Most of these weeds can be controlled with herbicides, but this can be expensive and is not always practicable. A competitive grass pasture is the best long-term method of control. Biological control is also relevant for some species.

Thirty five plant species are declared noxious in Queensland under the Rural Lands Protection Act, 1985. Declaration is made within various categories, each requiring a different level of control.

For further information contact The Department of Lands in Emerald.

Land degradation 7

Introduction

Land degradation in the Central Highlands relates to soil and pasture management. The major issues for each are outlined below.

Soil degradation

- erosion by water and wind
- siltation
- salinity
- compaction

Pasture degradation

- regrowth
- weeds
- pasture rundown
- loss of habitat or natural vegetation

Soil degradation

Erosion

Erosion poses the single greatest threat to the long-term productivity of cultivated land in the Central Highlands. Table 7.1 shows the susceptibility of the various AMUs to sheet, rill, gully and wind erosion. The erodibility ratings are not based on hard data but rather on local experience. The arable soils, with their high clay content and consequent low infiltration rate, are very susceptible to sheet, rill and gully erosion. Springton, Turkey Creek, Glen Idol and Glengallan AMUs can be prone to wind erosion when the cultivated surface is left bare or unprotected by stubble.

The AMUs suited predominantly to grazing are generally less susceptible to sheet and rill erosion. However Lascelles, Highlands, Glengallan and Glen Idol AMUs can be prone to bad gully erosion if something initiates the problem e.g. track or cattle pad.

Cultivation is largely restricted to land with less than 3% slope and is not recommended on slopes greater than 4%. On any slope greater than 0.5% mechanical structures (contour banks and waterways) are required in conjunction with conservation cropping techniques.

Table 7.1. *Susceptibility of AMUs to erosion*

AMU	**Sheet erosion**	**Rill erosion**	**Gully erosion**	**Wind erosion**
Adelong	M	L	L	L
College	M	L	L	L
Dooruna	L	L	L	L
Duckponds	L	L	M	M
Glengallan	**H**	M	**H**	M
Glen Idol	L	M	**H**	M
Highlands	M	M	**H**	L
Isaac	**H**	L	M	M
Jimbaroo	**H**	**H**	**H**	L
Kia-Ora	**H**	**H**	M	L
Lascelles	**H**	M	**H**	M
Lonesome	L	L	L	L
Moramana	M	M	L	L
Orion	**H**	**H**	**H**	L
Picardy	M	L	L	L
Rolleston	M	M	L	L
Springton	**H**	M	M	**H**
Turkey Creek	**H**	**H**	M	M

H = High Susceptibility

M = Medium Susceptibility

L = Low Susceptibility

A large amount of visible erosion is associated with man-made operations; for example roads, railway lines, power lines, table drains and road-cross drainage structures.

Roadside erosion is a problem with all AMUs with erodible soils because water flows become concentrated and considerable gullies can form. The subsequent siltation affects road-cross drainages.

A large area of alluvial flats are farmed (e.g. Adelong, Picardy, Moramana AMUs) and, from time to time, they are subject to erosive flooding. Although these events occur infrequently the whole plough layer can be removed (erosion) from one area and deposited in another (siltation).

Specifications for soil conservation works

Broad based contour banks are the recommended structures for controlling erosion on the cracking clay soils. At least 95% of the farming occurs on cracking clay soils, while the remaining 5% is suitable for narrow based contour banks.

Contour banks are surveyed at a grade of 0.15 to 0.18%. In some special situations the grade may be varied to avoid an obstacle. Bank length can be up to 2500 m. Anything longer than this would need to be specially designed. Settled bank height is 60 cm to handle a 1 in 10 year runoff event and have 15 cm freeboard (distance between top water level and nominal bank crest).

Contour bank spacings are shown in Table 7.2.

Table 7.2. *Contour bank spacing in the Central Highlands*

Slope %	Vertical Interval (m)	Horizontal Interval (m)
0.5	0.75	150
1.0	1.2	120
1.5	1.5	100
2.0	1.8	90
2.5	2.0	80
3.0	2.1	70
4.0	2.4	60

Generally the horizontal interval is no greater than 150 m and no less than 60 m. Some local variation of vertical interval can occur within these horizontal limits.

Diversion banks can have a grade up to 0.5% and are usually designed in each case. The design period is the 1 in 10 year runoff event.

All waterways are designed primarily for a 1 in 10 year runoff event but in some cases may be designed for a higher flow depending on how critical they are.

Salinity

There are two types of salinity to consider in the Central Highlands:

- inherent salinity, where the soil has naturally occurring high chloride levels; and
- man-made or secondary salinity from rising watertables.

AMUs with naturally occurring high chloride levels in some part of the soil profile are Dooruna, College, and Lonesome. AMUs likely to suffer from rising watertables are Orion, Jimbaroo, Picardy, Springton, and Glen Idol.

The most extensive areas of salinity in the Central Highlands are in parts of the Emerald Irrigation Area. Water percolates from irrigation or head ditches on Orion or Jimbaroo AMUs into the porous basalt and flows through it until it meets the deeper clays of Picardy AMU. There, in the lower part of the landscape, it emerges at the surface where salts then accumulate due to evaporation.

This problem is being reduced by lining the irrigation channels, better water use efficiency of the irrigation system, and piped drainage to intercept water flows in the basalt.

In the dryland situation, rising watertables from seeps or springs can cause salts to accumulate on the surface, killing crops or preventing them from establishing. None of these outbreaks are much bigger than half a hectare, where they mainly show up as a result of rainfall infiltrating the porous basalt. This happens either from occurrences of a year of higher than normal rainfall or the surface water pouring down cracks in the clay soils straight into the basalt below, as is often the case after a dry period.

Salting is most likely to occur where watertables are close to the surface. The presence of black tea tree (*Melaleuca bracteata*) indicates a shallow watertable, and if cleared, saline areas can develop. Black tea tree should not be cleared under any circumstances.

Compaction

Soil compaction is a problem which is only now being recognised. Fortunately, with almost all of the irrigated and dryland cropping occurring on cracking clays with high calcium and magnesium ratios, recovery occurs naturally when the soil dries out. For a more in-depth discussion of the compaction issue refer to Section 6 *Agricultural land management*.

Pasture degradation

Regrowth

This problem is restricted to grazing areas where inadequate attention has been paid to the control of regrowth, or grazing pressure has been such that no grass build-up has occurred to allow regular burning.

Every AMU except Orion, Jimbaroo, Dooruna and Kia-Ora is prone to regrowth problems or has the potential to develop it. The AMUs which are the exceptions do not have this regrowth problem because they characterise the 'open downs' type country.

The number of species that regrow are enormous. The most common are: brigalow, Dawson gum, poplar box, currant bush and false sandalwood. Methods of control are discussed in Section 6 *Agricultural land management*.

Weeds

Weeds can invade run-down pastures and in the worst cases render them useless. Parthenium is the prime example of an invading weed. In some areas around Clermont it dominates natural bluegrass pastures because, at one stage, the pasture was severely overgrazed and the parthenium established itself. In most pastures, strategic spelling to allow the grass to outcompete the weed is the answer.

Other weeds posing serious problems in some areas are rubber vine, prickly acacia, parkinsonia and chinee apple. Chemical control is the usual option.

Pasture rundown

As the developed pastures of the scrub soils get older, the amount of available nitrogen decreases. In these situations pasture productivity drops back considerably to a level at which it finally stabilises.

This productivity level can be increased, but not up to the original level, by pasture renovation techniques. This usually involves a ripping or ploughing to kill some plants and cause a release of nitrogen from the decaying root mass. This result is relatively short-lived (a few years) before it reverts to the stable level prior to the renovation. The evidence is inconclusive that the increased grass production from the renovation techniques, leads to economic animal weight gains.

Loss of natural habitat

Virtually all the original scrub of the Central Highlands has been cleared and developed. Most of the remaining areas of scrub still standing are in National Parks, on slopes that are too steep to clear, or on individual properties whose owners want to retain it. These residual areas of scrub are isolated from one another, surrounded by farming land or improved pasture land. There are generally no vegetation corridors linking them together or linking them to larger wildlife habitats. This may eventually doom the plant and animal species that are trapped in these areas.

The forest country is now in the process of being cleared and developed for improved grazing. An effort should be made to ensure that the same problems which occurred with the scrub country are not allowed to happen with it.

Some of the regrowth control techniques available today, (for example Graslan and blade ploughing) are so effective that regrowth may only have to be treated once. Therefore, if future linking corridors or shelter belts are to regrow from suckers and seedlings, their position must be worked out prior to any regrowth control operations.

Water resources in the Central Highlands 8

Alex Loy
Water Resources, Brisbane

Introduction

The main river systems which drain the Central Highlands area are the Nogoa-Mackenzie River system in the Fitzroy Region and the Belyando-Suttor River system in the Burdekin Region. These systems and several of the other streams that run through the area, notably the Comet River, which enters the upstream end of the Mackenzie River, are shown in Figure 8.1.

Rainfall varies considerably over the area, with average annual rainfall varying from about 500 mm in the west to 700 mm in the east. Mean annual isohyets and statistics for various rainfall stations are given in Section 2.

Surface water resources

The estimated mean annual discharge for several of the major streams in the area are given in Table 8.1.

Table 8.1. *Stream discharge and runoff rates in the Central Highlands*

Stream	Catchment Area (km^2)	Mean Annual Discharge (ML)	Mean annual runoff (mm)
Nogoa River	27 895	880 000	32
Comet River	17 200	645 000	38
Mackenzie River (upstream of Isaac River junction)	52 335	1 730 000	33
Belyando River	35 530	890 000	25
Suttor River	49 820	1 833 654	37

Note: mean annual runoff = mean annual discharge/ catchment area

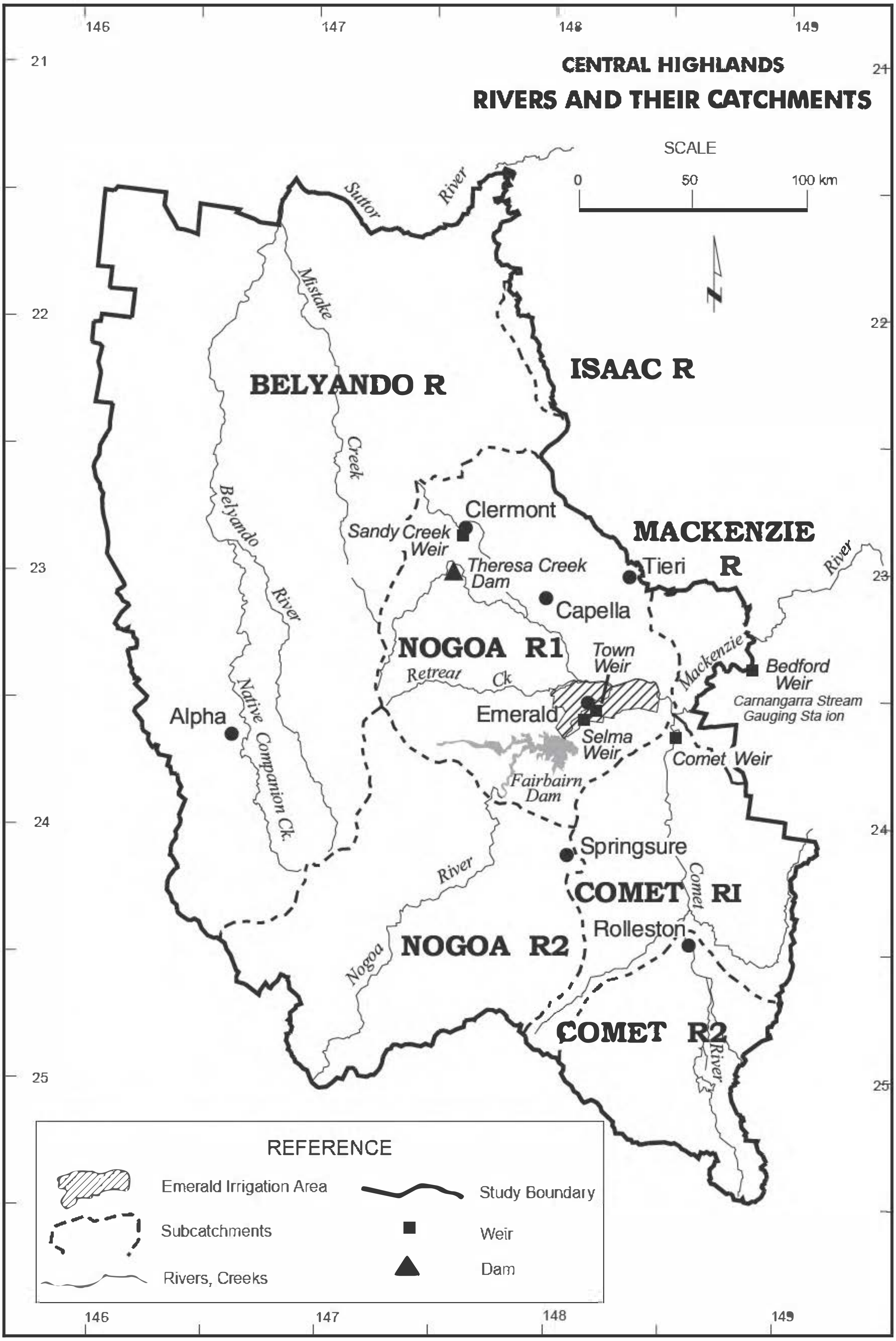


Figure 8.1. *Rivers and their catchmments for the Central Highlands*

Streamflow is seasonal with pronounced summer runoff but there is considerable variation from year to year.

To indicate this seasonality in streamflow, monthly and annual statistics for the Mackenzie River at Carnangarra are shown in Table 8.2.

Table 8.2. *Annual streamflow variability for the Mackenzie River*

Stream and AMTD Gauging Station Name and No. Period of Record	**Mackenzie River at 585.8 km Carnangarra 130103 1967 - 1989**		
Monthly Discharge (ML)	Maximum	Mean	Minimum
JAN	1 959 969	270 030	1 341
FEB	2 048 936	368 432	5
MAR	1 066 761	117 448	0
APR	162 810	23 116	88
MAY	2 583 451	182 334	0
JUNE	587 357	44 091	0
JULY	90 781	13 041	0
AUG	112 471	9 130	0
SEPT	116 050	7 332	0
OCT	100 864	7 187	0
NOV	72 764	11 317	0
DEC	1 503 667	139 293	4
Annual Discharge (ML)	4 946 831	1 225 359	3 834

Groundwater resources

Sources of groundwater in the area are predominantly alluvium, sedimentary rocks and fractured rocks.

The distribution of these aquifers in the Central Highlands area is shown in Figure 8.2

Groundwater quality varies from low (less than 3000 mg/L total dissolved ions) to high (greater than 3000 mg/L total dissolved ions) salinity (see Figure 8.3).

Pumping rates from the aquifers are generally low with the exception of the areas of sedimentary rocks and some parts of the alluvium. In Figure 8.3, a low pumping rate is classed as less than 10 L/s and a high pumping rate is greater than 10 L/s.

Regional groundwater quality and pumping rate ability are shown in Figure 8.3.

Licences are required for all of the area as it is classed as a Groundwater Licensing Declared Area.

Water resources development

Existing development

Irrigated agriculture in the area is concentrated at Emerald and along the Nogoa/Mackenzie Rivers. One of the benefits of irrigation is that yield fluctuations are minimised. Details of areas irrigated in sub-catchments are shown in Table 8.3.

Table 8.3. *Areas irrigated 1990*

Sub-catchment	Area irrigated (ha)	Main crop
Mackenzie R.	165	pasture
Nogoa R1	16 347	cotton
Nogoa R2	254	pasture
Comet R1	1 081	pasture
Comet R2	227	pasture

The Belyando Shire, excluding the area covered by the Nogoa R1 subcatchment, is very sparsely irrigated. The main land use in this area is pasture.

Major water conservation storages have been developed to provide water supplies for irrigation in the Emerald Irrigation Area (EIA), the coal mining industry north and east of Emerald, and several urban centres. These storages are shown in Figure 8.1.

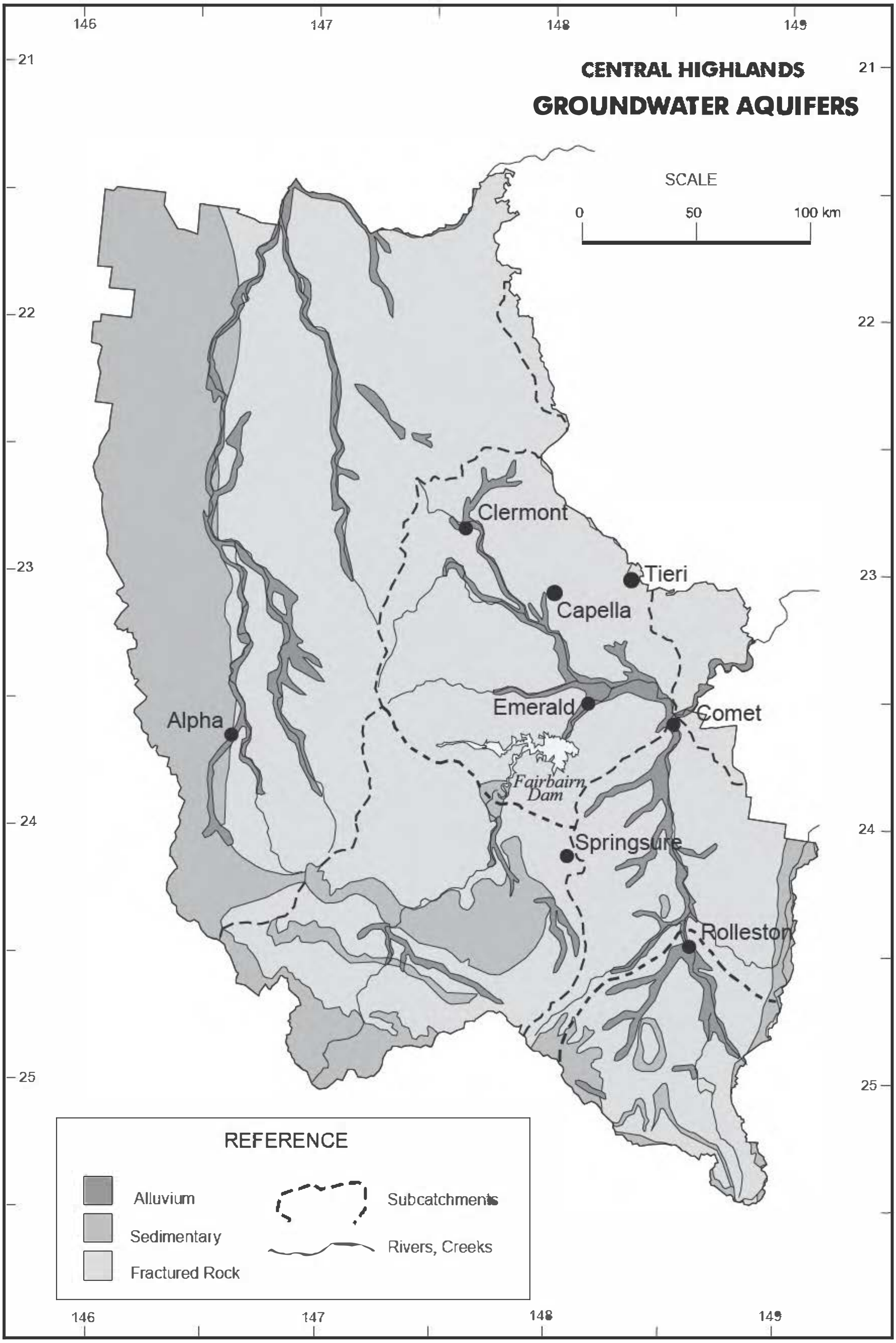


Figure 8.2. *Groundwater aquifers: Central Highlands*

The EIA is the major water conservation project in the area. Irrigation, urban, industrial and stock and domestic supplies are provided from a storage system comprising Fairbairn Dam, Selma and Town Weirs on the Nogoa River and Bedford, Bingegang and Tartrus Weirs on the Mackenzie River.

Water from Fairbairn Dam for irrigation farms is diverted through 73 kilometres of channel on the left bank of the Nogoa River (the Selma system) and 53 kilometres of channel on the right bank (the Weemah system). Irrigation supplies are also provided from the regulated section and weirs of the Nogoa and Mackenzie Rivers from Fairbairn Dam to the Springton Creek junction which is some 90 kilometres downstream of Tartrus Weir. The EIA and regulated section of the Nogoa and Mackenzie Rivers are shown on Figure 8.1.

Urban water is obtained from surface water and groundwater supplies as indicated in Table 8.4.

Selma, Bedford and Bingegang Weirs also provide water supplies for coal mines.

Table 8.4. *Urban water supplies*

Shire	**Town**	**Surface water supply**	**Groundwater supply**
Bauhinia	Rolleston	Nil	Groundwater bores
	Springsure	Nil	Groundwater bores
Belyando	Clermont	Theresa Creek dam Sandy Creek weir	Bore water available but not presently (standby) being used
Emerald	Emerald	Town weir	Nil
	Comet	Comet weir	Nil
	Gemfields	Nil	Bore water
Jericho	Alpha	Nil	Bore water
Peak Downs	Capella	Capella creek water harvesting	Part bore water
	Tieri	Oakey Creek pipeline - Bedford weir	Nil

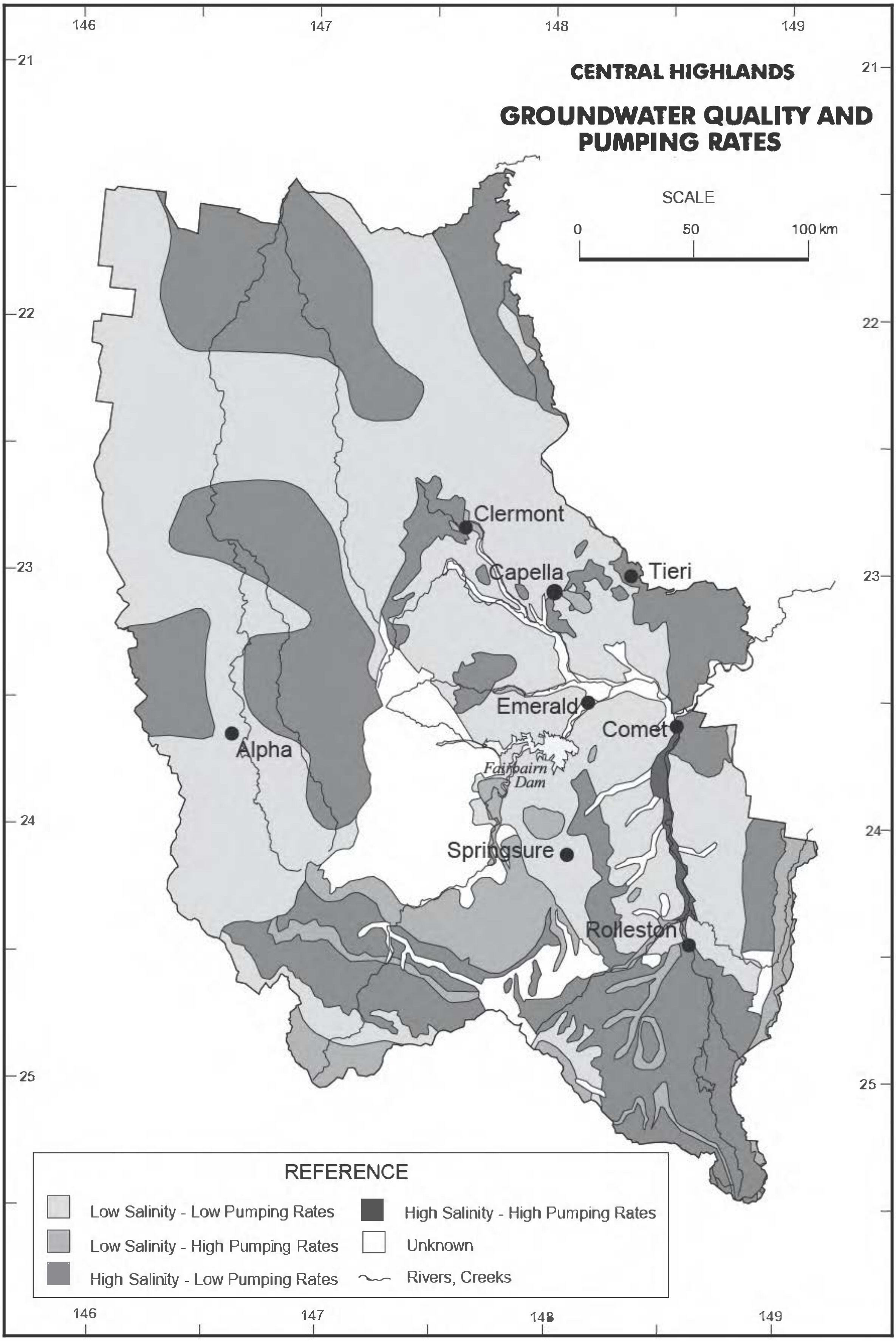


Figure 8.3. *Groundwater quality and pumping rates: Central Highlands*

Future development

Development within the EIA is restricted by the availability of suitable land and by the capacity of the delivery system.

There is some potential within the irrigation area for the development of land which was previously considered less suitable for irrigation development. The introduction of farming alternatives, such as horticultural crops has potential. This has been proven with the development of a large citrus farm in the area.

The greatest development potential in the Emerald district exists along the reaches of the Nogoa and Mackenzie River systems. Regulated releases will become available and potential exists for increased benefits through water harvesting practices.

There is potential for development of up to approximately 21 000 ha of land well suited to irrigation development in the Nogoa-Mackenzie system. Areas identified as having the greatest potential for irrigation development are areas of the EIA to the Comet River junction, Bingegang Weir and Gordon to Lake Mary.

Of these areas the EIA to Comet River junction showed the greatest short-term potential with landholders indicating development intentions within a five year period.

In the Belyando-Suttor Rivers system, no major areas of potential development have been identified. However, water harvesting opportunities are available along the Belyando and Suttor Rivers and some of their tributaries.

Water quality

A water quality monitoring program exists in the EIA. Issues of concern for water quality are agricultural chemicals, salinity and turbidity (suspended sediment).

In other areas of the region, a network is being established to enable long-term monitoring of water quality. Issues of concern include discharges from mining activity and soil erosion.

Analyses of water samples to date have shown that the quality of water has been acceptable. Chemical concentrations have been well within accepted limits.

Monitoring of groundwater quality has not been as extensively undertaken as other water quality monitoring. Water samples from groundwater bores are analysed as the need arises.

Land development and nature conservation 9

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Seeking common ground

National parks and other reserves play an essential role in conserving biological diversity and protecting genetic variation of fauna and flora.

The Nature Conservation Act, which replaces the National Parks and Wildlife Act and Fauna Conservation Act, makes extensive provision for forging voluntary conservation agreements with landholders over key areas on private lands. However, even with the establishment of a network of voluntary Nature Refuge areas to support the conservation objectives, the great majority of rural lands will continue to be used essentially for primary production.

Technological advances in timber treatment, through mechanical and chemical means, are facilitating continued large scale clearing and fragmentation of timbered habitat. The development of the majority of brigalow and softwood scrub communities means that attention has switched to eucalypt forests and woodlands.

Ultimately such practices, if continued at the present scale, will severely affect biological resource values.

Property management planning provides the means for successfully integrating nature conservation practices with practical property management.

Benefits of nature conservation

Considering the benefits of wildlife (fauna and flora) is warranted in any assessment of development options aimed at maintaining or improving the productivity and sustainability of agricultural systems. These benefits are detailed below.

Environmental influences of natural timber communities:

- erosion control through stabilisation of slopes and banks through soil binding, reduction in soil surface rainfall impact and runoff velocity and from slowing of stream flow during flooding;
- bolstering atmospheric moisture levels through transpiration of water unavailable to shallow rooted ground layer vegetation, evaporation from the tree canopy and through influences on air stream speed and direction;

- salinity control through regulation of water movement in the soil profile and accompanying watertable levels;
- regulation of ground temperatures through surface shading, reduction of reflective radiation and cooling of low level air streams; and
- contribution to soil nutrient cycles through tapping nutrients at depth and depositing surface organic matter through leaf fall and decay.

Use of natural timber as a management tool:

- shade and shelter for stock in the paddock and in holding yards;
- source of building and fencing material;
- control of movement of mustered stock via corridors and between strategically placed timber blocks;
- regulating grazing intensity through strategic location of shade areas both on and off watering points;
- reducing evaporation from water storages through shade timber, retained away from walls and by the wash area;
- protecting the heavily grazed “sacrifice” area around watering points;
- regulating fire direction and intensity through a mosaic of developed and uncleared areas;
- protecting fencelines from stock and fires through retention of timbered corridors on either side;
- source of seedling and sucker material for possible future rehabilitation needs, and as a source of genetic material; and
- reference point for monitoring possible impacts of property management practices on undeveloped as against developed areas.

The role of native predators in regulating or controlling both native and introduced pest fauna and insect populations is substantial though difficult to quantify.

However, research has indicated that in healthy eucalypt woodlands birds may eat about half of the insects produced, while small mammals, predatory insects and spiders, take a significant proportion of the rest.

Dingoes perform an important role in controlling the numbers of pigs, wallabies and kangaroos in some areas.

A fundamental reason for maintaining environmental diversity is to ensure the preservation of the range of genetic resources contained in living organisms. Native species in any given region could have unrealised potential in such areas as food technology, human health, fabrics and biological control. Allied to this is the aesthetic and spiritual qualities of wildlife and the natural landscape for contemplation and inspiration.

The major ethical concern for wildlife conservation is that the natural process of extinction and change is being dramatically increased through human activity. Unplanned use of the environment, which reduces natural diversity, will deny future generations options to enrich their lives, particularly if changes brought about by increasingly sophisticated technologies are largely irreversible. Central to this is the contention that the community must establish what is desired regarding the character of the local living environment that is to be mainatined for the long-term.

The wildlife of the Central Highlands is typically Australian. Simply stated, you cannot live in the bush without the bush.

Conservation principles within the Central Highlands

The Central Highlands Fauna Survey conducted by the Queensland National Parks and Wildlife Service from 1974 to 1976 provides a clear insight into the rich and diverse native fauna of the area.

The total count for the four groups surveyed was 209 birds, 42 mammals, 65 reptiles and 18 frog species.

Planning for implementation of effective conservation practices requires consideration of basic biological principles assessed from the wildlife's point of view, prior to development.

Considerations include patterns of habitat use; size and shape of retained habitat; ecological diversity; occurrence of natural features and dispersal mechanisms of animal populations.

Brigalow and eucalypt complexes dominate in the Central Highlands. These can be broadly grouped into open woodlands, woodlands, open forests and riverine forests on watercourses and adjacent alluvial flats. Riverine species include river red gum, blue gum, Moreton Bay ash and coolibah.

The scattered softwood scrubs occurring through the Central Highlands require special consideration in formulating conservation strategies, as a range of wildlife species occur in these rainforest-related communities at the western limits of their inland distribution. Therefore, clearing of a relatively small patch of softwood scrub will affect wildlife populations far greater than clearing an equal area of eucalypt woodland or brigalow scrub.

Voluntary Nature Refuge agreements will play a key role in future protection of these heavily fragmented remnants, which generally occur on highly productive soils.

Wildlife conservation strategies in Central Queensland have relied heavily on the continued existence of large tracts of eucalypt and other timbered habitat with a good ground cover. This is particularly necessary for the survival of species such as small ground mammals which are less able to cope with human land use.

Hardier species such as kangaroos, larger wallabies and brushtail possums still require interconnecting blocks of timbered habitat to:

- cope with changing land management practices;
- maintain genetic interchange between their sub-populations; and
- re-populate areas subject to natural events such as bushfires.

The conservation values of the eucalypt communities cannot be overstated. For example, during survey work about 40 per cent of ground mammals of the Central Highlands were never recorded in the brigalow scrubs and associated communities, occurring only in eucalypt habitat types.

The protection of riverine corridors is vital as they provide habitat, food or shelter for the most diverse cross-section of resident, migratory and transitory fauna species of any grouping of eucalypt communities in the Central Highlands.

Such corridors are the most readily definable features of the natural landscape, allowing full opportunity for property developers to design viable retention areas.

A number of the more mobile fauna species range freely through all vegetation types. However, when all four species groups are considered as a whole, their occurrence is characteristically patchy rather than being distributed more or less evenly throughout the environment. Such patchiness largely reflects landscape features, soil types and the distribution, structure and species composition of the vegetation communities. The range of environmental attributes influencing the distribution of wildlife need to be adequately represented in a mosaic of conservation management areas.

To achieve this a strategically planned network of large interconnecting blocks of uncleared land throughout the Central Highlands is fundamental.

Diversity

Maximising diversity between habitats and within habitats is essential. It lies in careful selection of retained timber blocks for nature conservation. Variations in such factors as geology, soil type, slope and drainage should be incorporated. These in turn, influence the species composition and structural makeup of vegetation communities.

Within a habitat, a greater diversity of species can be encouraged by a range of features. These will include variations in natural ground cover, water bodies of varying depth and permanence, and the presence of mature trees with hollow limbs.

The zone of overlap or ecotone where one habitat grades into another is important also as there may be a greater diversity of plants and other features than in any of the individual habitats.

Size and shape

Retaining large continuous areas of diverse habitat maximises opportunities for wildlife. Larger species generally require extensive areas for feeding, shelter and breeding. Conversely patchy distribution may reflect more specialised needs.

Fragmentation of extensive areas by clearing to produce smaller blocks can still be more productive for wildlife than retaining continuous areas of uniform habitat. However, it is essential to retain interconnecting ‘corridors’ of native vegetation to enable small, less mobile fauna species to disperse. This reduces risk of exposure or predation, and provides channels of movement for wide ranging migratory and nomadic fauna.

The narrower the width of any corridor or block of retained vegetation becomes, the greater will be the effect on the timber margins from surrounding development and land use.

The term edge effect refers to changes in micro-climate, makeup and structure of vegetation, influenced by such factors as grazing, fire and predation rates by native and introduced predators.

Such factors tend to work in favour of farm land species which are able to adapt to altered or new conditions. While this group includes species such as magpies and peewees which are of obvious economic benefit to primary producers, the overall result of increasing edge effect include a reduction or loss of insectivores naturally adapted to timbered habitat, with consequent effects on tree health.

Grazing levels can significantly influence this process. Understorey vegetation and seedling recruitment of the tree cover can be suppressed by overgrazing of woodland and old trees decline rapidly, partly through inadequate control of insect populations.

Conservation planning

Shire approach

As trustees of Local Government Reserves and through involvement with management of stock routes and road corridors, Local Authorities can play a direct role in ensuring the retention of a mosaic of natural features throughout the Shire.

Shire Strategic Plans, formulated through community consultation, provide a further opportunity to positively influence land use on a catchment level.

Individual property approach

Through the use of air photographs and property plans prepared by landholders in consultation with government and private consultants, planning features can be progressively incorporated into existing operations.

Examples include fencing of paddocks in sympathy with AMUs rather than by rectangles; by introducing laneways for stock movement; and by establishing a water supply which is reliable and drought-proof.

Legislative requirements on clearing of leasehold rural lands in pastoral areas of the State are managed by means of conditions applied to tree clearing permits issued by the Department of Lands.

These guidelines provide a starting point for conserving elements of natural diversity on individual holdings. Landholders can maximise the value of conservation efforts through adopting a planning approach with a long-term perspective, which can ultimately improve commercial property value.

Conservation practice

Circumstances for individual holdings will vary according to the level of past development. Heavily cleared areas would need to be managed for partial regeneration.

There are no guarantees of certain success. When considering the area of timber to be retained the overriding principle to remember is 'the bigger the better'.

With the best of intentions there is little point in investing time, effort and capital if retained natural areas stand little chance of surviving the passage of time.

As a general rule, the following strategies aimed at integrating effective retention of natural diversity into property management planning in the Central Highlands are recommended:

- use the resources of the DPI to aid in the preparation of a property plan, based on a photobase which identifies land resource areas and AMUs;
- as much continuous uncleared habitat as possible should be retained, through such developing practices as aerially sowing improved pasture varieties into standing timber;
- the minimum area to be retained on a property should include 20% of **all AMUs** suitable for development. Thus for grazing properties this strategy should aim at retention of 50% or more of the total property area as native vegetation. Mixed grazing and farming concerns in more closely settled areas should aim at 30% or more retention;

- when fencing is planned as part of the development it should follow AMU boundaries, which would simplify determination of clearing patterns; stocking rates or farming practices could then be geared to the productivity and physical characteristics of the individual paddocks;
- blocks of timber retained as sections of the original stand should be as wide as possible to minimise ‘edge effect’ from the effects of fire, grazing and native and introduced insect pests;
- raking or pushing material for burning should not occur into or along the edges of retention areas;
- large blocks of timber could be left in paddock corners or even be fenced off altogether, (for example, in rough terrain with difficult access) enabling property investment to be concentrated in key development areas;
- the smallest block of timber retained should be at least 10 hectares in size to lessen the degradation of understorey and ground vegetation cover, and to allow for partial fencing for regenerative purposes where required;
- continuous timber corridors, 200 m wide, should be retained adjacent to a 25 m cleared mustering corridor bordering boundary fences; the aim should be to link blocks to habitats on neighbouring properties, Local Government Reserves, stock routes, roads and watercourses, via unbroken corridors of timber at least 100 metres wide bordering selected fencelines;
- for large areas strips of timber at least 100 metres wide and up to 400 metres apart can be left along the contour with contour banks on either side, and be linked to adjoining habitat. However, while strips have practical advantages, (including more even grazing patterns), and provide for a more diverse and attractive landscape than clearing on a face, the land types thus retained may be severely fragmented and reduced in conservation value.
- fewer large strips are preferable to narrow designs, which should not be included in the area calculated as ‘retained’;

- corridors and patches provided by drainage lines, depressions and standing water bodies are a vital consideration; recommendations are compounded because in soils and associated timber types in these typically fauna rich areas, vary in width depending on stream velocities and flood levels. An additional consideration is that sloping terrain unsuitable for clearing may extend well out from watercourses before levelling out to flood plains or terraces.

The following recommendations reflect this variability:

- undisturbed corridors of timber at least 250 to 500 metres wide should be retained along both sides of major river channels;
- where multiple channels occur timber should be retained in a corridor extending 250 metres out from the outer channel on both sides of the stream complex;
- belts of timber 200 metres wide should be retained around the full perimeter of lakes, swamps and lagoons;
- corridors of timber at least 150 to 250 metres wide should be retained on both sides of minor rivers and major creek channels.
- where multiple channels occur timber should be retained in a corridor extending 150 metres out from the outer channel on both sides of the stream complex;
- gullies supporting riverine communities such as river red gum should remain bordered with belts of timber at least 100 metres wide on both sides, particularly where trees are containing soil erosion through root binding;
- riverine communities such as coolibah, river red gum and blue gum occurring on drainage depressions are often well spaced, and because of their high fauna value should be retained in their entirety where possible;
- clearing and blade ploughing should be carried out along the contour; timber should be retained on AMUs with high erosion potential (including areas subject to inundation), and on water intake zones and salinity prone areas; and

- clearing should not occur in the Central Highlands area on slopes steeper than 15% or where the above conditions prevail.

Such recommendations may seem unrealistic in economic terms to some primary producers. However, landholders in the Central Highlands are increasingly finding cause for regret concerning the impact and extent of initial development.

Further reading

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A list of common names for plants commonly found in the Central Highlands — Appendix I

Common name	Botanical name
Trees and shrubs	
Bancroft's wattle	*Acacia bancroftii*
Bat's wing coral tree	*Erythrina vespertilio*
Bead bush	*Spartothamnella juncea*
Bean tree	*Cassia brewsteri*
Beefwood	*Grevillea striata*
Belah	*Casuarina cristata*
Bendee	*Acacia catenulata*
Bitter bark	*Alstonia constricta*
Black tea tree	*Melaleuca bracteata*
Black wattle	*Acacia salicina*
Blackwood	*Acacia argyrodendron*
Bloodwood	*Eucalyptus terminalis*
Bonewood	*Macropteranthes leichhardtii*
Boonaree	*Heterodendrum oleifolium*
Bootlace oak	*Hakea lorea*
Bottlebrush	*Melaleuca* spp.
Brigalow	*Acacia harpophylla*
Broad leaved bottletree	*Brachychiton australis*
Broom bush	*Apophyllum anomalum*
Brush hovea	*Hovea longipes*
Buddah sandalwood	*Eremophila mitchellii*
Budgeroo	*Lysicarpus angustifolius*
Bull oak	*Casuarina luehmannii*
Butter bush	*Cassia nemophila*
Caustic creeper	*Sarcostemma australe*
Caustic vine	*Sarcostemma australe*
Chinee apple	*Ziziphus mauritiana*
Chinese lantern	*Abutilon auritum*
Coolibah	*Eucalyptus coolabah*
Corkwood oak	*Hakea fraseri*
Coughbush	*Cassinia laevis*

Common name	Botanical name
Creek wilga	*Eremophila bignoniiflora*
Crows ash	*Flindersia australis*
Currant bush	*Carissa ovata*
Cypress pine	*Callitris columellaris*
Dawson gum	*Eucalyptus cambageana*
Dead finish	*Albizia basaltica*
Desert cassia	*Cassia nemophila*
Desert oak	*Acacia coriacea*
Doolan	*Acacia salicina*
Dysentery plant	*Grewia latifolia*
Early flowering black wattle	*Acacia leiocalyx*
Ellangowan poison bush	*Myoporum deserti*
Emu apple	*Owenia acidula*
False sandalwood	*Eremophila mitchellii*
Forest oak	*Allocasuarina torulosa*
Fuschia bush	*Eremophila maculata*
Ghost gum	*Eucalyptus papuana*
Gidgee	*Acacia cambagei*
Gidyea	*Acacia cambagei*
Gooramurra	*Eremophila bignoniiflora*
Grass tree	*Xanthorrhoea* spp.
Grey mistletoe	*Amyema quandang*
Gum-topped bloodwood	*Eucalyptus erythrophloia*
Gum-topped box	*Eucalyptus moluccana*
Heart leaf poison bush	*Gastrolobium grandiflorum*
Holly	*Denhamia oleaster*
Hoop pine	*Araucaria cunninghamii*
Hop bush	*Dodonaea filifolia*
Hovea pea	*Hovea longipes*

Common name	Botanical name
Ironwood	*Acacia excelsa*
Kurrajong	*Brachychiton populneus*
Lancewood	*Acacia shirleyi*
Leichhardt bean	*Cassia brewsteri*
Lemon scented gum	*Eucalyptus citriodora*
Leucaena	*Leucaena leucocephala*
Lignum	*Muehlenbeckia cunninghamii*
Limebush	*Eremocitrus glauca*
Lolly bush	*Clerodendrum floribundum*
Longfruited bloodwood	*Eucalyptus dolichocarpa*
Mimosa bush	*Acacia farnesiana*
Moreton Bay ash	*Eucalyptus tessellaris*
Mountain coolibah	*Eucalyptus orgadophila*
Myall	*Acacia pendula*
Myrtle tree	*Canthium oleifolium*
Narrow leaf beefwood	*Grevillea parallela*
Narrow leaf croton	*Croton phebalioides*
Narrow leaf bumble-tree	*Capparis loranthifolia*
Narrow leaved bottletree	*Brachychiton rupestris*
Narrow leaved ironbark	*Eucalyptus crebra*
Native grape	*Cissus opaca*
Native jasmine	*Jasminum didymum*
Native jasmine	*Jasminum didymum* subsp. *racemosum*
Nelia	*Acacia oswaldii*
Nipan	*Capparis lasiantha*
Normanton box	*Eucalyptus normantonensis*
Ooline	*Cadellia pentastylis*
Orchid	*Cymbidium canaliculatum*
Orchid	*Dendrobium canaliculatum*

Common name	Botanical name
Peachbush	*Ehretia membranifolia*
Peach leaf poison bush	*Trema aspera*
Poison peach	*Trema aspera*
Poplar box	*Eucalyptus populnea*
Poplar gum	*Eucalyptus platyphylla*
Prickly pears	*Opuntia* spp.
Prickly pine	*Bursaria incana*
Queensland blue gum	*Eucalyptus tereticornis*
Queensland cascarilla bark	*Croton insularis*
Queensland peppermint	*Eucalyptus exserta*
Queensland grey ironbark	*Eucalyptus drepanophylla*
Quinine tree	*Petalostigma pubescens*
Red ash	*Alphitonia excelsa*
Red bauhinia	*Lysiphyllum carronii*
Reid river box	*Eucalyptus brownii*
River oak	*Casuarina cunninghamiana*
River red gum	*Eucalyptus camaldulensis*
Rose apple	*Angophora costata*
Rosewood	*Acacia rhodoxylon*
Rough silkpod	*Parsonsia lanceolata*
Roughbark apple	*Angophora floribunda*
Ruby saltbush	*Enchylaena tomentosa*
Rusty gum	*Angophora costata*
Sally wattle	*Acacia salicina*
Sandalwood	*Santalum lanceolatum*
Scrub boonaree	*Heterodendrum diversifolium*
Scrub leopardwood	*Flindersia dissosperma*
Scrub cherry	*Exocarpos latifolius*
Silver leaved ironbark	*Eucalyptus melanophloia*
Slender wattle	*Acacia leptostachya*

Common name	Botanical name
Small-leaf ebony	*Diospyros ferrea*
Small-leaved acalypha	*Acalypha capillipes*
Smoothbark apple	*Angophora costata*
Soap bush	*Alphitonia excelsa*
Spotted gum	*Eucalyptus maculata*
Split jack	*Capparis lasiantha*
Sticky hopbush	*Dodonaea viscosa*
Supplejack	*Ventilago viminalis*
Tea tree	*Leptospermum* spp.
Tree zamia	*Cycas media*
True sandalwood	*Santalum lanceolatum*
Turkey bush	*Erythroxylum australe*
Velvety tree pear	*Opuntia tomentosa*
Vine tree	*Ventilago viminalis*
Wallaby apple	*Citriobatus spinescens*
White bauhinia	*Lysiphyllum hookeri*
Whitewood	*Atalaya hemiglauca*
Wild orange	*Capparis mitchellii*
Wilga	*Geijera parviflora*
Yapunyah	*Eucalyptus thozetiana*
Yarran	*Acacia homolophylla*
Yellow-berry bush	*Maytenus cunninghamii*
Yellowjack	*Eucalyptus similis*
Yellow jacket	*Eucalyptus peltata*
Yellowwood	*Terminalia oblongata*
Zamia	*Macrozamia moorei*

Common name	Botanical name
Grasses And Forbs	
Aleman grass	*Echinochloa polystochya*
Angleton grass	*Dichanthium aristatum*
Awnless barnyard grass	*Echinochloa colona*
Barbwire grass	*Cymbopogon refractus*
Barley mitchell grass	*Astrebla pectinata*
Barley grass	*Panicum decompositum*
Belah grass	*Paspalidium gracile*
Black speargrass	*Heteropogon contortus*
Bluegrasses	*Dichanthium* spp.
Brigalow grass	*Paspalidium caespitosum*
Brigalow burr	*Sclerolaena tetracuspis*
Buffel grass	*Cenchrus ciliaris*
Bull mitchell grass	*Astrebla squarrosa*
Cane grass	*Ophiuros megaphyllus*
Canegrass	*Leptochloa* spp.
Citronella grass	*Cymbopogon bombycinus*
Coolibah grass	*Thellungia advena*
Creeping bluegrass	*Bothriochloa insculpta*
Curly windmill grass	*Enteropogon acicularis*
Curly mitchell grass	*Astrebla lappacea*
Desert bluegrass	*Bothriochloa ewartiana*
Dog burr	*Sclerolaena tetracuspis*
Downs lucerne	*Rhynchosia minima* var. *australis*
Downs nutgrass	*Cyperus bifax*
Fairy grass	*Sporobolus caroli*
Feather top	*Aristida latifolia*
Flinders grass	*Iseilema vaginiflorum*
Forest bluegrass	*Bothriochloa bladhii*

Common name	Botanical name
Galvanised burr	*Sclerolaena birchii*
Golden beard grass	*Chrysopogon fallax*
Green panic	*Panicum maximum* var. *trichoglume*
Hairy panic	*Panicum effusum*
Hooky grass	*Ancistrachne uncinulata*
Hymenachne	*Hymenachne amplexicanlis*
Indian bluegrass	*Bothriochloa pertusa*
Kangaroo grass	*Themeda triandra*
Lovegrasses	*Eragrostis* spp.
Native sensitive plant	*Neptunia gracilis*
Nutgrass	*Cyperus rotundus*
Old man saltbush	*Atriplex nummularia*
Para grass	*Brachiaria mutica*
Pea glycine	*Glycine tabacina*
Pigweed	*Portulaca oleracea*
Pitted bluegrass	*Bothriochloa decipiens*
Purple pigeon grass	*Setaria incrassata*
Queensland bluegrass	*Dichanthium sericeum*
Rat's tail grass	*Sporobolus elongatus*
Rat's tail couch	*Sporobolus mitchellii*
Rattlepod	*Crotalaria dissitiflora*
Red Natal grass	*Melinis repens*
Rhodes grass	*Chloris gayana*
Rhynchosia	*Rhynchosia minima* var. *minima*
Rushes	*Juncus* spp.

Common name	Botanical name
Sago grass	*Paspalidium globoideum*
Seca stylo	*Stylosanthes scabra*
Sedges	*Cyperus* spp.
Sesbania pea	*Sesbania cannabina*
Shot grass	*Paspalidium globoideum*
Silk sorghum	*Sorghum* spp.
Silky brown top	*Eulalia aurea*
Siratro	*Macroptilium atropurpureum*
Slender chloris	*Chloris divaricata*
Slender sedge	*Cyperus gracilis*
Slender panic	*Paspalidium gracile*
Spider grass	*Enteropogon acicularis*
Spinifex	*Triodia mitchellii*
Tarvine	*Boerhavia diffusa*
Three awned speargrass	*Aristida ramosa*
Wallaby grass	*Danthonia* spp.
White speargrass	*Aristida leptopoda*
Wiregrass	*Aristida ramosa*
Wynn cassia	*Cassia rotundifolia*
Yabila grass	*Panicum queenslandicum*
Yakka grass	*Sporobolus caroli*

Botanical name	Common name
Trees and Shrubs	
Abutilon auritum	Chinese lantern
Acacia argyrodendron	Blackwood
Acacia bancroftii	Bancroft's wattle
Acacia cambagei	Gidgee, Gidyea
Acacia catenulata	Bendee
Acacia coriacea	Desert oak
Acacia excelsa	Ironwood
Acacia farnesiana	Mimosa bush
Acacia harpophylla	Brigalow
Acacia homolophylla	Yarran
Acacia leiocalyx	Early flowering black wattle
Acacia leptostachya	Slender wattle
Acacia oswaldii	Nelia
Acacia pendula	Myall
Acacia rhodoxylon	Rosewood
Acacia salicina	Sally wattle, Doolan, Black wattle
Acacia shirleyi	Lancewood
Acalypha capillipes	Small-leaved acalypha
Albizia basaltica	Dead finish
Allocasuarina torulosa	Forest oak
Alphitonia excelsa	Red ash, Soap bush
Alstonia constricta	Bitter bark
Amyema quandang	Grey mistletoe
Angophora costata	Smoothbark apple, Rose apple, Rusty gum
Angophora floribunda	Roughbark apple
Apophyllum anomalum	Broom bush
Araucaria cunninghamii	Hoop pine
Atalaya hemiglauca	Whitewood
Brachychiton australis	Broad leaved bottletree
Brachychiton populneus	Kurrajong

Botanical name	Common name
Brachychiton rupestris	Narrow leaved bottletree
Bursaria incana	Prickly pine
Cadellia pentastylis	Ooline
Callitris columellaris	Cypress pine
Canthium oleifolium	Myrtle tree
Capparis lasiantha	Nipan, Split jack
Capparis loranthifolia	Narrowleaf bumble
Capparis mitchellii	Wild orange
Carissa ovata	Currant bush
Cassia brewsteri	Bean tree, Leichhardt bean
Cassinia laevis	Coughbush
Cassia nemophila	Desert cassia, Butter bush
Casuarina cristata	Belah
Casuarina cunninghamiana	River oak
Casuarina luehmannii	Bull oak
Cissus opaca	Native grape
Citriobatus spinescens	Wallaby apple
Clerodendrum floribundum	Lolly bush
Croton phebalioides	Narrow leaf croton
Croton insularis	Queensland cascarilla bark
Cycas media	Tree zamia
Cymbidium canaliculatum	Orchid
Dendrobium canaliculatum	Orchid
Denhamia oleaster	Holly
Diospyros ferrea	Small-leaf ebony
Dodonaea filifolia	Hop bush
Dodonaea viscosa	Sticky hopbush
Ehretia membranifolia	Peachbush
Enchylaena tomentosa	Ruby saltbush
Eremocitrus glauca	Limebush
Eremophila bignoniiflora	Creek wilga, gooramurra
Eremophila maculata	Fuschia bush

Botanical name	Common name
Eremophila mitchellii	False sandalwood, Buddah sandalwood
Erythrina vespertilio	Bat's wing coral tree
Erythroxylum australe	Turkey bush
Eucalyptus brownii	Reid river box
Eucalyptus camaldulensis	River red gum
Eucalyptus cambageana	Dawson gum
Eucalyptus citriodora	Lemon scented gum
Eucalyptus coolabah	Coolibah
Eucalyptus crebra	Narrow leaved ironbark
Eucalyptus dolichocarpa	Longfruited bloodwood
Eucalyptus drepanophylla	Queensland grey ironbark
Eucalyptus erythrophloia	Gum-topped bloodwood
Eucalyptus exserta	Queensland peppermint
Eucalyptus maculata	Spotted gum
Eucalyptus melanophloia	Silver leaved ironbark
Eucalyptus moluccana	Gum-topped box
Eucalyptus normantonensis	Normanton box
Eucalyptus orgadophila	Mountain coolibah
Eucalyptus papuana	Ghost gum
Eucaluptus peltata	Yellow jacket
Eucalyptus platyphylla	Poplar gum
Eucalyptus populnea	Poplar box
Eucalyptus similis	Yellowjack
Eucalyptus tereticornis	Queensland blue gum
Eucalyptus terminalis	Bloodwood
Eucalyptus tessellaris	Moreton Bay ash
Eucalyptus thozetiana	Yapunyah
Exocarpos latifolius	Scrub cherry
Flindersia dissosperma	Scrub leopardwood
Flindersia australis	Crows ash
Gastrolobium grandiflorum	Heart leaf poison bush
Geijera parviflora	Wilga

Botanical name	Common name
Grevillea parallela	Narrow leaf beefwood
Grevillea striata	Beefwood
Grewia latifolia	Dysentery plant
Hakea lorea	Bootlace oak
Hakea fraseri	Corkwood oak
Heterodendrum diversifolium	Scrub boonaree
Heterodendrum oleifolium	Boonaree
Hovea longifolia	
Hovea longipes	Hovea pea, Brush hovea
Jasminum didymum	Native jasmine
Jasminum didymum subsp. *racemosum*	Native jasmine
Leptospermum spp.	Tea tree
Leucaena leucocephala	Leucaena
Lysicarpus angustifolius	Budgeroo
Lysiphyllum carronii	Red bauhinia
Lysiphyllum hookeri	White bauhinia
Macropteranthes leichhardtii	Bonewood
Macrozamia moorei	Zamia
Maytenus cunninghamii	Yellow-berry bush
Melaleuca bracteata	Black tea tree
Melaleuca spp.	Bottlebrush
Muehlenbeckia cunninghamii	Lignum
Myoporum deserti	Ellangowan poison bush
Opuntia spp.	Prickly pears
Opuntia tomentosa	Velvety tree pear
Owenia acidula	Emu apple
Parsonsia lanceolata	Rough silkpod
Petalostigma pubescens	Quinine tree

Botanical name	Common name
Santalum lanceolatum	Sandalwood, True sandalwood
Sarcostemma australe	Caustic vine, Caustic creeper
Solanum parvifolium	
Spartothamnella juncea	Bead bush
Terminalia oblongata	Yellowwood
Trema aspera	Poison peach, peach leaf poison bush
Ventilago viminalis	Vine tree, Supplejack
Xanthorrhoea spp.	Grass tree
Ziziphus mauritiana	Chinee apple

Grasses & Forbs

Ancistrachne uncinulata	Hooky grass
Aristida ramosa	Wiregrass, Three awned spear grass
Aristida latifolia	Feather top
Aristida leptopoda	White speargrass
Astrebla lappacea	Curly mitchell grass
Astrebla pectinata	Barley mitchell grass
Astrebla squarrosa	Bull mitchell grass
Atriplex nummularia	Old man saltbush
Boerhavia diffusa	Tarvine
Bothriochloa bladhii	Forest bluegrass
Bothriochloa decipiens	Pitted bluegrass
Bothriochloa ewartiana	Desert bluegrass
Bothriochloa pertusa	Indian bluegrass
Brachiaria mutica	Para grass

Botanical name	Common name
Cassia rotundifolia	Wynn cassia
Cenchrus ciliaris	Buffel grass
Chloris divaricata	Slender chloris
Chloris gayana	Rhodes grass
Chrysopogon fallax	Golden beard grass
Crotalaria dissitiflora	Rattlepod
Cymbopogon bombycinus	Citronella grass
Cymbopogon refractus	Barbwire grass
Cyperus spp.	Sedges
Cyperus bifax	Downs nutgrass
Cyperus gracilis	Slender sedge
Cyperus rotundus	Nutgrass
Danthonia spp.	Wallaby grass
Dichanthium aristatum	Angleton grass
Dichanthium sericeum	Queensland bluegrass
Dichanthium spp.	Bluegrasses
Echinochloa colona	Awnless barnyard grass
Echinochloa polystochya	Aleman grass
Enteropogon acicularis	Curly windmill grass, spider grass
Eragrostis spp.	Lovegrasses
Eulalia aurea	Silky brown top
Glycine tabacina	Pea glycine
Heteropogon contortus	Black speargrass
Iseilema vaginiflorum	Flinders grass
Juncus spp.	Rushes
Leptochloa spp.	Cane grass

Botanical name	Common name
Macroptilium atropurpureum	Siratro
Melinis repens	Red Natal grass
Neptunia gracilis	Native sensitive plant
Ophiuros megaphyllus	Cane grass
Panicum decompositum	Barley grass
Panicum effusum	Hairy panic
Panicum maximum var. *trichoglume*	Green panic
Panicum queenslandicum	Yabila grass
Paspalidium caespitosum	Brigalow grass
Paspalidium globoideum	Shot grass, sago grass
Paspalidium gracile	Slender panic, belah grass
Portulaca filifolia	
Portulaca oleracea	Pigweed
Rhynchosia minima var *minima*	Rhynchosia
Rhynchosia minima var *australis*	Downs lucerne
Sclerolaena birchii	Galvanized burr
Sclerolaena tetracuspis	Brigalow burr, dog burr
Sesbania cannabina	Sesbania pea
Setaria incrassata	Purple pigeon grass
Sorghum spp.	Silk sorghum
Sporobolus caroli	Fairy grass, Yakka grass
Sporobolus elongatus	Rat's tail grass
Sporobolus mitchellii	Rat's tail couch
Stylosanthes scabra	Seca stylo
Thellungia advena	Coolibah grass
Themeda triandra	Kangaroo grass
Triodia mitchellii	Spinifex

Appendix II

Summary climatic data

Table II.1. *Mean daily maximum temperatures (°C) for four centres in the Central Highlands*

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Twin Hills	34.7	33.4	32.7	30.8	27.0	24.2	24.1	26.7	29.8	32.8	35.2	25.4	30.7
Clermont	34.2	32.9	31.8	29.4	25.9	23.0	22.9	25.2	28.6	31.8	34.1	34.9	29.6
Emerald	34.2	33.2	32.0	29.6	25.9	22.8	22.6	24.9	28.3	31.7	33.8	34.6	29.5
Springsure	34.0	32.3	31.4	28.9	25.2	22.2	21.9	23.7	27.4	30.6	33.2	34.7	29.0

Table II.2. *Mean daily minimum temperatures (°C) for four centres in the Central Highlands*

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Twin Hills	22.2	21.8	19.8	16.0	11.9	7.9	6.8	9.3	12.0	16.1	19.5	21.3	15.5
Clermont	21.4	20.9	19.2	15.4	11.1	7.8	6.4	7.9	11.8	15.9	18.9	20.7	14.8
Emerald	21.3	21.1	19.6	15.6	11.4	8.5	7.1	8.1	11.9	16.1	19.0	20.7	15.0
Springsure	20.6	20.3	18.8	14.2	10.3	6.4	5.6	6.9	10.6	14.7	17.5	19.7	14.0

Analytical data for representative soil profiles

Appendix III

This appendix contains both the detailed description and the analytical data for 18 soils. The soils selected for analysis are representative of the range of soils within AMUs.

Where possible, soil profile samples have been taken from virgin sites to provide an indication of 'base-line' nutrient levels. Bulked surface samples, denoted by the letter 'B', have been taken from an adjacent cultivated paddock of the same soil.

The soil classification in this section applies to the described and sampled profile.

1. ADELONG

REPRESENTATIVE PROFILE

AMU: ADELONG

SITE: EME S4

AMG REFERENCE: 649 500 mE 7 370 500 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.24

AUSTRALIAN SOIL CLASSIFICATION: Calcareous, self-mulching, grey vertosol

SUBSTRATE MATERIAL: Alluvium

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Flood plain

VEGETATION
STRUCTURAL FORM: Dryland cultivation
DOMINANT SPECIES:

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Self-mulching

HORIZON	DEPTH	DESCRIPTION
AP	0 to 0.10 m	Greyish brown (7.5YR 4/2), heavy clay, few fine calcareous segregations. Clear to:
B21	0 to 1.00 m	Greyish brown (7.5YR 4/2), heavy clay, very few calcareous segregations. Diffuse to:
B22	1.00 to 1.50 m	Greyish brown (7.5YR 4/4), havy clay, very few calcareous segregations.

				Particle Size (%)				Exch. Cations (m.eo/100g)					Total Elements (%)				Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B 0.10	8.5	.15	.002	2	9	19	71	55	42	12	2.6	1.5	4.7	.115	1.17	.030		26	.38
0.10	8.5	.14	.001	1	10	21	71	54	36	18	.99	.78	1.8	.100	1.04	.026		28	.52
0.30	8.8	.27	.003	1	10	20	71	52	26	19	.69	.96	1.3	.100	1.06	.035		27	.75
0.60	9.0	.50	.014	1	11	22	70	49	26	20	1.2	.84	2.4	.101	1.08	.047		27	.75
0.90	8.8	.82	.039	1	12	21	69	49	25	20	5.6	.17	11.4	.098	1.09	.063			
1.20	8.6	1.02	.041																
1.40	8.0	1.04	.056																
1.50	8.5	1.02	.060																

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K	DTPA-extr (mg/kg)			
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
†B 0.10	1.4	0.10	508	52	1.8	15	5	1.5	0.5

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

2. COLLEGE

REPRESENTATIVE PROFILE

AMU: COLLEGE

SITE: ESH TS1

AMG REFERENCE: 622 100 mE 7 395 700 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.24

AUSTRALIAN SOIL CLASSIFICATION: Calcareous, crusty, grey vertosol

SUBSTRATE MATERIAL: Alluvium

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Alluvial plain

VEGETATION
STRUCTURAL FORM: Open forest
DOMINANT SPECIES: *Acacia harpophylla, Lysiphyllum carronii, Eremophila mitchelli, Flindersia dissosperma*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Crusting

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.02 m	Greyish yellow-brown. (10YR 4/2); medium clay; strong medium granular with thin (2 - 5 mm) crust; very hard. Clear to:
A12	0.02 to 0.30 m	Greyish yellow-brown (10YR 4/2); medium clay; strong, medium and coarse subangular and angular blocky; very hard; very small amounts of concretionary lime; some roots. Diffuse to:
B11	0.30 to 0.80 m	Greyish yellow-brown (10YR 4/2); medium clay; strong medium and coarse lenticular; very hard; very small amounts of concretionary lime; some roots. Clear to:
B22fm	0.80 to 1.20 m	Dark greyish yellow (2.5Y 5/2); medium clay; strong medium and coarse lenticular, very hard; large amounts of manganese veins and mangans; few roots only. Diffuse to:
B23	1.20 to 2.60 m	As 0.80 to 1.20 m but no manganese veins or mangans. Diffuse to:
D	2.60 to 3.00 m	Yellowish grey (2.5Y 5/3); sandy clay; no roots.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	7.5	.078	.005	16	30	11	43	24	13	8.4	0.8	0.3	3.4					14	
0.30	8.2	.439	.056	14	27	11	48	25	13	10.7	3.0	0.1	11.8					15	
0.60	7.5	.860	.152	15	29	10	46	23	8.4	10.5	3.7	0.2	16.4					15	
0.90	6.5	.801	.149	15	29	10	46	22	5.3	9.2	3.2	0.1	14.7					16	
1.10	5.5	.823	.157	14	28	11	47	22	5.8	10.0	3.1	0.1	14.3						
1.30	5.1	.824	.154	13	29	11	47	22	5.6	9.6	3.4	0.2	15.7						
1.50	4.9	.804	.149	13	30	11	46	20	4.4	8.6	3.1	0.2	15.3						

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg)		Extractable K (meq %)	DTPA-extr (mg/kg)			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
0.10	1.05	0.05	8						

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

3. DOORUNA

REPRESENTATIVE PROFILE

AMU: DOORUNA

SITE: KCM S2

AMG REFERENCE: 552 000 mE 7 562 300 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.25

AUSTRALIAN SOIL CLASSIFICATION: Sodic, crusty, grey vertosol

SUBSTRATE MATERIAL:

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Level plain

VEGETATION
STRUCTURAL FORM: Low isolated clump of trees
DOMINANT SPECIES: *Acacia harpophylla, Panicum queenlandicum, Astrebla spp.*

PROFILE MORPHLOGY: (Depression profile)

CONDITION OF SURFACE SOIL WHEN DRY: Surface crust, periodic cracking

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.02 m	Greyish brown. (7.5YR 4/2); moist, yellowish grey (2.54Y 4/1) dry ; medium heavy clay; no coarse fragments; strong 10-20 mm subangular blocky secondary, parting to moderate 2-5 mm granular primary; dry; loose. Gradual to:
B21	0.02 to 0.30 m	Greyish brown (7.5YR 4/2) moist; medium heavy clay; very few small pebbles, subrounded quartz; moderate 50-100 mm subangular blocky secondary, parting to moderate 10-20 mm subangular blocky primary; dry; moderately strong. Abrupt to:
B22	0.30 to 0.80 m	Greyish brown (7.5YR 4/2) moist; medium heavy clay; no coarse fragments; lenticular; dry moderately strong; few medium gypseous crystals, few fine manganiferous veins. Diffuse to:
B23?	0.80 to 1.30 m	Dull reddish brown (5YR 4/3) moist; common medium distinct gley mottles, very few fine prominent yellow mottles; medium heavy clay; very few small pebbles, subrounded quartz; lenticular; dry; very firm; very few medium gypseous crystals. Diffuse to:
D?	1.30 to 1.70 m	Greenish grey (7.5GY 5/1) moist and dull reddish brown (5YR 4/3) moist; very few fine prominent yellow mottles, very few medium prominent red mottles; medium heavy clay; no coarse fragments; lenticular, dry; very firm.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B0.10	6.9	.09	.006																
0.10	6.7	.17	.018	3	16	18	68	38	16	13	2.3	.08	6.1	.02	<.01	.03		20	.56
0.30	6.1	1.5	.104	3	15	17	66	37	17	14	5.5	.04	14.9	.01	<.01	.12		22	.42
0.60	5.4	4.0	.217	3	14	15	69	36	38	16	8.8	.04	24.4	.01	<.01	.51		21	.50
0.90	4.9	2.6	.227	2	12	15	72	37	16	16	8.9	.04	24.1	.02	<.01	.16		21	.51
1.20	4.6	2.9	.249	1	10	13	77	40	23	18	9.8	.11	24.5	.01	<.01	.20		23	.52
1.50	4.6	2.2	.259	1	8	12	83	52	19	22	12	.03	23.1	.01	<.01	.07		28	.56

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Bicarb.	Extractable K (meq %)	Fe	DTPA-extr (mg/kg) Mn	Cu	Zn
†B0.10	0.5	0.04	4	5	0.07	34	69	1.4	0.5

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

4. DUCKPONDS

REPRESENTATIVE PROFILE

AMU: DUCKPONDS

SITE: ATE 9

AMG REFERENCE: 639 400 mE 7 382 300 mN ZONE 55

GREAT SOIL GROUP: Red earth

PRINCIPAL PROFILE FORM: Gn 2.12

AUSTRALIAN SOIL CLASSIFICATION: Haplic, mesotrophic, red kandosol

SUBSTRATE MATERIAL: Sandstone

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1%

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Plateau

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES:

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.10 m	Dark reddish brown (5YR 3/4) moist; light clay; very week; few ferruginous nodules.
B21	0.10 to 0.50 m	Dark reddish brown (2.5YR 3/4) moist; light clay; few ferruginous nodules.
B22	0.50 to 1.00 m	Dull reddish brown (2.5YR 4/4) moist; medium clay; few ferruginous nodules.

				Particle Size (%)				Exch. Cations (m.eo/100g)					Total Elements (%)				Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
†B0.10	5.4	.06	.003																
0.10	4.9	.07	.001	28	28	13	31	11	2.0	.67	<.1	.60	♎1.0	.060	.23	.019	19	10	.34
0.30	4.9	.04	.001	29	28	10	31	8	2.0	.69	<.1	.30	♎1.0	.051	.20	.015	19	10	.36
0.60	5.8	.03	.001	27	25	9	37	8	3.4	.76	<.1	.15	♎1.0	.049	.16	.013	20	11	.36
1.00	6.2	.02	.001	29	29	14	33							.045	.15				

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	DTPA-extr (mg/kg) Mn	DTPA-extr (mg/kg) Cu	DTPA-extr (mg/kg) Zn
†B0.10			20	22	0.54	31	40	1.3	1.4
0.10	1.0	0.08	10	15	0.50				
0.20	0.8	0.05	6	9	0.37				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

5. GLENGALLAN

REPRESENTATIVE PROFILE

AMU: GLENGALLAN

SITE: ESH Dd

AMG REFERENCE: 619 450 mE 7 393 600 mN ZONE 55

GREAT SOIL GROUP: Solodic

PRINCIPAL PROFILE FORM: Dd 1.43

AUSTRALIAN SOIL CLASSIFICATION: Bleached-sodic, hypercalcic, brown dermosol

SUBSTRATE MATERIAL: Tertiary sediments

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Lower mid-slope of undulating plain

VEGETATION

STRUCTURAL FORM: Shrubby woodland

DOMINANT SPECIES: *Eucalyptus cambageana, Acacia harpophylla, Eremophila mitchellii, Carissa ovata*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.05 m	Brownish black (10YR 3/1); clay loam; massive; slightly hard but hard setting surface; some roots. Sharp to:
A2	0.05 m	Thin (<2 mm) conspicuous bleach. Sharp to:
B21t	0.05 to 0.20 m	Brownish black (10YR 3/2); medium heavy clay; strong fine prismatic; very hard; moderate number of roots. Gradual to:
B22tca	0.20 to 1.05 m	Brown (7.5YR 4/3); medium heavy clay; strong fine prismatic; very hard; some calcium carbonate concretions (approx 5 mm diameter); some roots. Gradual to:
B23t	1.05 to 1.45 m	Dull yellowish brown (10YR 5/3); medium clay; strong fine prismatic; hard; few roots. Diffuse to:
D1	1.45 to 2.10 m	As above but light clay. Diffuse to:
D2	2.10 to 2.65 m	Dull brown (7.5YR 4/5); sandy clay; weak angular blocky; slightly hard. Diffuse to:
D3	2.65 to 3.00 m	Dull brown (7.5YR 5/5); light sandy clay loam; massive; slightly hard.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
0.10	6.5	.06	<.001	28	37	11	24	13.1	6.9	4.7	0.5	0.3	3.8						
0.30	8.4	.24	.002	25	32	10	33	16.8	8.2	7.4	1.6	0.1	9.5					8	
0.60	8.9	.47	.005	31	29	10	30	17.1	7.4	8.5	2.9	0.1	16.7					13	
0.90	8.9	.50	.007	26	33	11	32	15.9	4.2	9.1	4.1	0.1	25.8					13	
1.10	8.4	.56	.009	26	33	11	31	15.8	4.2	8.4	4.4	0.1	27.8					11	
1.30	7.2	.55		26	33	12	30	13.2	2.5	7.4	3.8	0.1	28.8					11	
1.40	6.6	.56																	

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K	DTPA-extr (mg/kg)			
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	1.06		34						

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

6. GLEN IDOL

REPRESENTATIVE PROFILE

AMU: GLEN IDOL

SITE: ATE 6

AMG REFERENCE: 632 400 mE 7 313 700 mN ZONE 55

GREAT SOIL GROUP: Solodic

PRINCIPAL PROFILE FORM: Dd 2.43

AUSTRALIAN SOIL CLASSIFICATION: Haplic, calcic, brown chromosol

SUBSTRATE MATERIAL: Sandstone

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1%

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Plain

VEGETATION
STRUCTURAL FORM: Open woodland
DOMINANT SPECIES: *Eucalyptus melanophloia, Eremophila mitchellii, Aristida spp., Bothriochloa ewartiana*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.10 m	Brownish black (10YR 2/2) moist; sandy clay loam; very few fragments, quartz; moderately weak.
A2	0.10 to 0.20 m	Dark brown (7.5YR 3/3) moist; sandy clay loam; very few fragments; quartz; moderately weak. Sharp to:
B21	0.20 to 0.30 m	Dull yellowish brown (10YR 4/3) moist; few mottles; heavy clay; very firm; few carbonate soft segregations, slightly calcareous.
B23	0.70 to 0.80 m	Dull yellowish brown (10YR 4./3) moist; few mottles; heavy clay; very firm, few carbonate soft segregations, moderately calcareous

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	6.7	.04	.001	46	25	10	14	14	6.0	4.7	<.10	.53		.028	.21	.013	18	6	.72
0.20	6.2	.02	.001																
0.30	6.1	.06	.006	34	20	9	35	21	7.3	9.4	.41	.23	4.7	.019	.19	.010	30	14	.59
0.60	7.3	.17	.020	29	16	8	44	27	11	15	1.0	..20		.015	.17	.010	34	17	.53
0.80	8.6	.32	.032	28	18	10	42							.016	.16	.012	35	17	.42

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
0.10	1.1	0.07	35	31	0.52	34	21	0.7	0.4
0.20	0.7	0.03	5	10	0.21				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

7. HIGHLANDS

REPRESENTATIVE PROFILE

AMU: HIGHLANDS

SITE: CGL 79

AMG REFERENCE: 705 900 mE 7 273 900 mN ZONE 55

GREAT SOIL GROUP: Lithosol

PRINCIPAL PROFILE FORM: Um 5.51

AUSTRALIAN SOIL CLASSIFICATION: Palic, paralithic, leptic tenosol

SUBSTRATE MATERIAL: Sandstone

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 18%

LANDFORM ELEMENT TYPE: Ridge

LANDFORM PATTERN TYPE: Rolling hills

VEGETATION
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: *Eucalyptus crebra, Eucalyptus citriodora, Eucalyptus drepanophylla, Acacia bancroftii, Acacia spp., Aristida spp., Cymbopogon refractus*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.15 m	Dark reddish brown (2.5YR 3/3) moist, dark reddish brown (5YR 3/4) dry; sandy clay loam; common medium pebbles, subangular sandstone; weak 2-5 mm subangular blocky; dry; moderately firm. Clear to:
Bw	0.15 to 0.30 m	Dark red (10R 3/6) moist; sandy clay loam; common medium pebbles, subangular sandstone; dry; moderately firm.

Surface sample only was analysed

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B0.10	6.1	.02	.001						2.5	2.4	.09	.60							

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
†B0.10			21	7.0					

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

8. ISAAC

REPRESENTATIVE PROFILE

AMU: ISAAC

SITE: CGL 108

AMG REFERENCE: 704 000 mE 7 520 000 mN ZONE 55

GREAT SOIL GROUP: No suitable group

PRINCIPAL PROFILE FORM: Um 5.52

AUSTRALIAN SOIL CLASSIFICATION: Haplic, fluvic, chernic, tenosol

SUBSTRATE MATERIAL:

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Levee

LANDFORM PATTERN TYPE: Level plain

VEGETATION
STRUCTURAL FORM: Tall open woodland
DOMINANT SPECIES: *Eucalyptus tereticornis, E. tessellaris, Acacia salicina*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.10 m	Brownish black (10YR 3/1) moist, brownish grey (10YR 5/1) dry; sandy clay loam; weak 2-5 mm subangular blocky; dry; moderately firm. Clear to:
A12?	0.10 to 0.60 m	Brownish black (10YR 3/1) moist; dull yellowish brown (10YR 3/1) moist; sandy clay loam; dry; moderately firm. Gradual to:
Bw1	0.60 to 1.00 m	Brown (7.5YR 4/3) moist; common mediuim distinct dark mottles; sandy clay loam; dry; moderately firm. Gradual to:
Bw2	1.00 to 1.45 m	Brown (7.5YR 4/4) moist; common fine distinct dark mottles; sandy clay loam; dry; moderately weak. Clear to:
D1	1.45 to 1.50 m	Brown (7.5YR 4/3) moist; brownish grey (7.5YR 4/1) moist; dry sporadically bleached; sandy light medium clay; dry; very firm.

Surface sample only was analysed

					Particle Size (%)			Exch. Cations (m.eo/100g)					Total Elements (%)				Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B0.10	6.7	.08	.006						6.0	2.8	.06	.65							

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
†B0.10			86	72					

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

9. JIMBAROO

REPRESENTATIVE PROFILE

AMU: JIMBAROO

SITE: ATE 1

AMG REFERENCE: 633 100 mE 7 357 600 mN ZONE 55

GREAT SOIL GROUP: Black earth

PRINCIPAL PROFILE FORM: Ug 5.12

AUSTRALIAN SOIL CLASSIFICATION: Haplic, slef-mulching, black vertosol

SUBSTRATE MATERIAL: Basalt

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 2%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE:

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES:

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

<u>HORIZON</u>	<u>DEPTH</u>	<u>DESCRIPTION</u>
A1	0 to 0.20 m	Brownish black (10YR 3/1) moist; medium clay; very few fragments, quartz; strong <2 mm granular; moderately firm
B2	0.20 to 0.30 m	Brownish black (10YR 3/1) moist; heavy clay; very few fragments, quartz; strong 10-20 mm angular blocky; very firm.
C	0.30 to 0.45 m	Yellowish grey (2.5YR 4/1) moist; heavy clay; many fragments, quartz; very firm; many carbonate concretions, moderately calcareous.

				Particle Size (%)				Exch. Cations (m.eo/100g)					Total Elements (%)				Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
0.10	7.7	.07	.002	5	12	14	67	73	54	22	.35	.93	0.5	.041	.41	.016	55		.44
0.30	8.1	.06	.001	4	13	15	68	75	56	22	.36	.45	0.5	.037	.34	.013	56	31	.45
0.45	8.6	.01	.001	25	16	16	42							.101	.43	.013	45	24	.52

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K		DTPA-extr (mg/kg)		
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	1.0	.08	99	17	0.72				
0.20	1.0	.08	88	13	0.01				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

10. KIA-ORA

REPRESENTATIVE PROFILE

AMU: KIA-ORA

SITE: ATE 7

AMG REFERENCE: 564 900 mE 7 315 100 mN ZONE 55

GREAT SOIL GROUP: Alluvial soil

PRINCIPAL PROFILE FORM: Ug 5.15

AUSTRALIAN SOIL CLASSIFICATION: Haplic, self-mulching, black vertosol

SUBSTRATE MATERIAL: Shale

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Plain

VEGETATION
STRUCTURAL FORM: Tussock grassland
DOMINANT SPECIES: *Dichanthium sericeum, Panicum queenslandicum*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.10 m	Brownish black (7.5YR 3/2); heavy clay; moderate 2-5 mm granular; moderately firm.
B21	0.10 to 0.30 m	Brownish black (7.5YR 3/2); heavy clay; very firm.
B22	0.30 to 0.60 m	Brownish black (10YR 3/2); medium clay; moderately weak.
B23	0.60 to 0.90 m	Dark brown (10YR 3/3); medium clay; moderately weak.

					Particle Size (%)			Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	7.1	.06	.001	6	28	19	49	38	19	15	.16	1.9	0.4	.104	1.66	.033	41	19	.61
0.20	7.1	.05	.001																
0.30	7.4	.05	.001	3	26	23	49	41	24	15	.62	.88	1.5	.096	1.55	.046	45	21	.69
0.60	8.1	.14	.011	2	27	27	47	41	24	17	1.6	.60	3.9	.104	1.57	.031	43	20	.56
0.90	8.6	.25	.020	2	33	28	39	39	22	16	1.7	.58	4.4	.110	1.57	.028	41	19	.58

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K	DTPA-extr (mg/kg)			
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	1.1	.11	564	132	1.9	32	19	1.6	0.5.
0.20	1.0	.09	564	86	1.5				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

11. LASCELLES

REPRESENTATIVE PROFILE

AMU: LASCELLES

SITE: ESH Dy

AMG REFERENCE: 619 400 mE 7 393 400 mN ZONE 55

GREAT SOIL GROUP: Solodized solonetz

PRINCIPAL PROFILE FORM: Dy 3.43

AUSTRALIAN SOIL CLASSIFICATION: Hypercalcic, subnatric, brown sodosol

SUBSTRATE MATERIAL: Tertiary sediments

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Lower mid-slope of gently undulating plain

VEGETATION

STRUCTURAL FORM: Shrubby woodland

DOMINANT SPECIES: *Ecualyptus populnea, Eucalyptus cambageana, Eremophila mitchellii, Carissa ovata*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.15 m	Brown (7.5YR 4/3); sandy loam; massive; slightly hard but hard setting surface; some roots. Gradual to:
A2	0.15 to 0.22 m	As above but bleached when dry. Sharp to:
B21t	0.22 to 0.70 m	Dull yellowish brown (10YR 5/4) with 10-15% grey mottles; medium clay; strong medium to coarse columnar breaking to moderate fine to medium prismatic; very hard; some roots. Gradual to:
B22tca	0.70 to 1.10 m	As above but with some accumulation of secondary lime and with few roots. Diffuse to:
D1	1.10 to 1.70 m	Dull reddish brown (5YR - 7.5YR 5/4) with 10% grey 5 mm mottles; medium clay; weak angular blocky; very hard; traces of manganese veins 120-130 cm only; no roots. Diffuse to:
D2	0.70 to 3.00 m	Dull brown (7.5YR 5/4); sandy clay becoming clay loam (sandy) with depth; weak angular blocky; slightly hard; no roots.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
0.10	6.7	.061	<.001	36	47	7	11	5.2	2.9	1.2	0.2	0.2	3.8					3.8	
0.25	6.4	.024	0	37	47	7	9	2.9	1.4	0.8	0.1	0.1	3.4					2.6	
0.35	6.8	.053	0	30	33	7	30	11.1	3.3	4.7	1.1	0.3	9.0					10	
0.55	8.3	.084	<.001	29	37	6	27	10.9	3.1	4.7	1.2	0.1	12.8					10	
0.70	9.2	.282	.003	28	38	6	27	12.7	3.3	5.5	2.6	0.1	20.5					10	
0.95	9.4	.527	.006	27	36	8	28	13.8	3.7	7.6	3.5	0.1	25.4					10	
1.15	9.2	.604	.008	25	35	9	31	15.5	3.3	9.1	3.9	0.1	25.2					12	
1.35	8.3	.576	.010	22	34	10	33	17.9	2.6	9.3	4.3	0.1	24.0						

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
0.10	0.69		8						

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

12a. LONESOME

REPRESENTATIVE PROFILE (mound)

AMU: LONESOME

SITE: EIL 46

AMG REFERENCE: 603 200 mE 7 402 200 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.28

AUSTRALIAN SOIL CLASSIFICATION: Sodic, pedal, grey vertosol

SUBSTRATE MATERIAL: Alluvium

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0 to 0.5%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Alluvial plain

VEGETATION
STRUCTURAL FORM: Low open forest
DOMINANT SPECIES: *Acacia harpophylla* (mallee habit)

PROFILE MORPHLOGY: (mound profile)

CONDITION OF SURFACE SOIL WHEN DRY: Crusty

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.02 m	Dark greyish yellow (2.5Y 5/2); medium heavy clay; 2-5 mm weak surface crust over strong coarse granular; very hard. Clear to:
A12	0.02 to 0.10 m	Dark greyish yellow (2.5Y 5/2); medium heavy clay; strong medium subangular and angular blocky; very hard. Gradual to:
A13ca	0.10 to 0.20 m	Dark greyish yellow (2.5Y 5/2); medium heavy clay; strong coarse subangular and angular blocky; extremely hard; moderate amounts of soft carbonate. Diffuse to:
B21	0.20 to 0.60 m	Dark greyish yellow (2.5Y 5/2); medium heavy clay; strong coarse lenticular; extremely hard; small amounts of soft and concretionary carbonate. Diffuse to:
B22	0.60 to 1.50 m	Dark greyish yellow (2.5Y 5/2); medium heavy clay; strong coarse lenticular; extremely hard; very small amounts of soft and concretionary carbonate.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	6.5	.20	.025	11	32	6	51	30	15	13	2.2	.61	7.3	.035	.41	.038	29	16	.60
0.30	8.5	.66	.099	8	17	10	65	33	15	17	4.5	.27	13.6	.020	.34	.051	34	17	.55
0.60	8.3	1.4	.193	13	28	5	54	29	11	16	5.5	.29	19.0	.018	.33	.058	31	16	.49
0.90	8.2	1.1	.188	10	28	4	58	31	10	17	6.1	.33	19.7	.017	.33	.045	35	17	.66
1.20	7.8	1.2	.191	8	26	10	56	33	9	17	6.6	.35	20.0	.016	.37	.037			
1.50	7.9	1.3	.194	10	26	5	59	32	8.4	18	7.0	.38	21.9						

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
0.10	2.0	0.08	20	18	0.48			2.2	0.5
0.20	1.5	0.04	12	7	0.23				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

12b. LONESOME

REPRESENTATIVE PROFILE (depression)

AMU: LONESOME

SITE: EIL 46

AMG REFERENCE: 603 200 mE 7 402 200 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.28

AUSTRALIAN SOIL CLASSIFICATION: Endohypersodic, pedal, grey vertosol

SUBSTRATE MATERIAL: Alluvium

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0 to 0.5%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE: Alluvial plain

VEGETATION

STRUCTURAL FORM: Low open forest

DOMINANT SPECIES: *Acacia harpophylla* (mallee habit)

PROFILE MORPHLOGY: (depression profile)

CONDITION OF SURFACE SOIL WHEN DRY: Crusty

HORIZON	DEPTH	DESCRIPTION
A11	0 to 0.02 m	Yellowish grey (2.5Y 5/1); medium heavy clay; 2-5 mm weak surface crust over strong medium subangular and angular blocky; extremely hard. Clear to:
A12	0.02 to 0.10 m	Yellowish grey (2.5Y 5/1); medium heavy clay; strong coarse subangular and angular blocky; extremely hard. Diffuse to:
B21	0.10 to 0.60 m	Yellowish grey (2.5Y 5/1): medium heavy clay; strong coarse lenticular; extremely hard. Diffuse to:
B22	0.60 to 1.30 m	Yellowish grey (2.5Y 6/1); medium heavy clay; strong coarse lenticular; extremely hard; very small amounts of manganese veins. Diffuse to:
B23	1.30 to 1.50 m	Yellowish grey (2.5Y 6/2); medium heavy clay; strong coarse lenticular; extremely hard; very small amounts of manganese veins.

					Particle Size (%)			Exch. Cations (m.eo/100g)					Total Elements (%)				Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	6.4	.11	.015	6	18	11	65	35	17	14	1.5	.95	4.3	.039	.47	.018	36	19	.62
0.30	7.1	.38	.062	5	15	12	68	32	19	13	2.2	.78	6.9	.039	.47	.020	38	20	.59
0.60	7.3	.80	.145	5	15	12	68	40	16	15	4.9	.73	12.3	.037	.46	.030	40	20	.75
0.90	6.6	.84	.149	6	15	12	67	34	11	15	5.7	.64	16.8	.031	.44	.039	39	20	.53
1.20	5.9	.76	.153	7	19	12	62	31	11	14	5.6	.53	18.1	.031	.42	.035			
1.50	5.6	.81	.159	7	20	11	62	31	9.6	13	5.4	.43	17.4						

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K	DTPA-extr (mg/kg)			
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	0.84	0.04	57	55	0.65			3.4	1.1
0.20	0.58	0.03	66	55	0.65				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

13. MORAMANA

REPRESENTATIVE PROFILE

AMU: MORAMANA

SITE: KCM S9

AMG REFERENCE: 553 600 mE 7 541 700 mN ZONE 55

GREAT SOIL GROUP: Brown clay

PRINCIPAL PROFILE FORM: Ug 5.3

AUSTRALIAN SOIL CLASSIFICATION: Calcareous, self-mulching, brown vertosol

SUBSTRATE MATERIAL:

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Flat

LANDFORM PATTERN TYPE: Level plain

VEGETATION
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: *Eucalyptus coolabah*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Self-mulching, periodic cracking

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.03 m	Brown (7.5YR 4/3) moist, brown (7.5YR 4/3) dry; medium heavy clay; strong 2-5 mm subangular blocky; dry; loose; few medium, carbonate nodules. Abrupt to:
B21	0.03 to 0.25 m	Brown (7.5YR 4/3) moist; medium heavy clay; dry; very firm; very few medium carbonate nodules, very few fine carbonate nodules. Clear to:
B22	0.25 to 1.30 m	Brown (7.5YR 4/3) moist; medium heavy clay; dry; very firm; very few medium carbonate nodules. Gradual to:
B23	1.30 to 1.85 m	Bright reddish brown (5YR 5/6) moist; very few fine prominent yellow mottles; medium heavy clay; dry; moderately firm; common medium manganiferous veins, few coarse gypseous crystals.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B0.10	7.9	.10	.002	5	17	16	66	56	37	17	.82	.31	1.5						.25
0.10	8.0	.10	.001											.02	.07	.03		26	
0.30	8.8	.11	.001	4	17	18	67	59	40	19	3.1	.10	5.3	.01	.05	.02		26	.30
0.60	8.9	.24	.016	2	17	15	67	56	35	20	5.8	.10	10.4	.01	.05	.03		27	.41
0.90	8.7	.73	.069	4	17	16	68	57	33	22	8.2	.10	14.4	.01	.05	.03		28	.43
1.20	8.4	1.0	.094	3	17	17	69	57	32	22	9.1	.11	16.0	.01	.07	.05		27	.44
1.50	8.0	2.0	.096	3	15	21	66	59	32	20	9.9	.13	16.8	.02	.07	.18		21	.42

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	DTPA-extr (mg/kg) Mn	DTPA-extr (mg/kg) Cu	DTPA-extr (mg/kg) Zn
†B0.10	1.0	.09	9	7	0.45	13	12	1.0	0.4

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

14. ORION

REPRESENTATIVE PROFILE

AMU: ORION

SITE: ATE 5

AMG REFERENCE: 640 600 mE 7 313 700 mN ZONE 55

GREAT SOIL GROUP: Black earth

PRINCIPAL PROFILE FORM: Ug 5.12

AUSTRALIAN SOIL CLASSIFICATION: Haplic, self-mulching, black vertosol

SUBSTRATE MATERIAL: Basalt

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 2%

LANDFORM ELEMENT TYPE: Plain

LANDFORM PATTERN TYPE:

VEGETATION

STRUCTURAL FORM: Tussock grassland

DOMINANT SPECIES: *Dichanthiun sericeum, Iseilema membranaceum, Panicum queenslandicum*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.10 m	Brownish black (10YR 2/2) moist; medium clay; very few fragments, quartz; strong <2 mm granular; moderately firm.
B21	0.10 to 0.50 m	Brownish black (10YR 2/2) moist; medium clay; very few fragments, quartz.
B22	0.50 to 0.60 m	Brownish black (10YR 2/2) moist; medium clay; many fragments, sedimentary rocks.

					Particle Size (%)				Exch. Cations (m.eo/100g)					Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	7.4	.05	.001	7	13	13	73	76	51	25	.32	.39	<1.0	.025	.11	.012	58	58	.36
0.20	7.0	.04	.001																
0.30	7.2	.03	.001	5	11	14	70	78	53	26	.44	.24	<1.0	.025	.10	.012	60	60	.37
0.60	7.9	.07	.001	9	11	11	70	78	53	26	.88	.20	1.1	.027	.10	.011	63	63	.36

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K		DTPA-extr (mg/kg)		
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	1.0	0.07	7	14	0.32	27	22	1.8	0.3
0.20	1.0	0.07	8	17	0.29				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

15. PICARDY

REPRESENTATIVE PROFILE

AMU: PICARDY

SITE: KCM S11

AMG REFERENCE: 553 000 mE 7 546 200 mN ZONE 55

GREAT SOIL GROUP: Brown clay

PRINCIPAL PROFILE FORM: Ug 5.34

AUSTRALIAN SOIL CLASSIFICATION: Calcareous, self-mulching, brown vertosol

SUBSTRATE MATERIAL: Tertiary sediments

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Flat

LANDFORM PATTERN TYPE: Level plain

VEGETATION

STRUCTURAL FORM: Tall sparse shrubland

DOMINANT SPECIES: *Acacia cambagei, Canthium spp., Apophyllum anomalum, Cenchrus ciliaris, Aristida spp.*

PROFILE MORPHLOGY: (mound profile)

CONDITION OF SURFACE SOIL WHEN DRY: Self-mulching, surface crust

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.03 m	Dull reddish brown (5YR 4/4) moist, brown (7.5YR 4/3) dry; medium clay; strong 2-5 mm subangular blocky; dry; loose; few medium carbonate nodules, very few coarse carbonate nodules. Clear to:
B21	0.03 to 0.30 m	Brown (7.5YR 4/3) moist; medium heavy clay; dry; very firm; few medium carbonate nodules. Gradual to:
B22	0.30 to 0.60 m	Brown (7.5YR 4/3) moist; medium heavy clay; very few small pebbles, subrounded quartz; dry; moderately strong; few medium carbonate nodules, very few fine carbonate soft segregations. Diffuse to:
B23	0.60 to 1.20 m	Brown (7.5YR 4/3) moist; medium heavy clay; very firm; common fine gypseous crystals, very few medium carbonate nodules. Diffuse to:
B24	1.20 to 1.80 m	Brown (7.5YR 4/4) moist; medium heavy clay; dry; very firm; many medium manganiferous veins, few medium carbonate nodules.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
†B	8.5	.15	.003																
0.10	8.5	.15	.002	12	15	15	57	53	46	10	.40	.55	.8	.09	.20	.08		22	.26
0.10	8.7	.20	.002	7	15	15	64	51	39	14	1.5	.27	2.9	.05	.13	.08		27	.22
0.30	8.6	.71	.008	4	18	12	67	51	34	17	4.8	.15	9.4	.03	.08	.12		24	.28
0.60	7.8	3.6	.068	3	16	11	71	50	31	16	8.6	.12	17.2	.02	.06	1.27		25	.09
0.90	8.1	2.3	.233	3	17	12	68	52	35	16	10	.13	19.2	.02	.06	.26		25	.38
1.20	8.2	2.0	.226	2	17	14	69	52	31	15	10	.13	19.2	.01	.05	.28		25	.40
1.50																			

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	DTPA-extr (mg/kg) Mn	DTPA-extr (mg/kg) Cu	DTPA-extr (mg/kg) Zn
†B0.10	1.7	0.17	56	54	0.62	13	8	1.4	0.7

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

16. ROLLESTON

REPRESENTATIVE PROFILE

AMU: ROLLESTON

SITE: ATE 27

AMG REFERENCE: 527 100 mE 7 537 500 mN ZONE 55

GREAT SOIL GROUP: Grey clay

PRINCIPAL PROFILE FORM: Ug 5.23

AUSTRALIAN SOIL CLASSIFICATION: Endoacidic, pedal, grey vertosol

SUBSTRATE MATERIAL:

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Plain

VEGETATION

STRUCTURAL FORM:

DOMINANT SPECIES: *Acacia cambagei, Terminalia oblongata, Geijera parviflora, Carissa ovata, Enteropogon acicularis, Panicum queenslandicum*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.10 m	Dark brown (10YR 3/3) moist; heavy clay; few fragments, quartz; moderate 10-20 mm angular blocky; very firm.
B21	0.10 to 0.50 m	Greyish yellow-brown (10YR 4/2) moist; heavy clay; few fragments, quartz.
B22	0.50 to 1.10 m	Greyish yellow-brown (10YR 4/2) moist; heavy clay; few fragments, quartz; few manganiferous nodules.
B23	1.10 to 1.20 m	Brown (7.5YR 4/3) moist; common red mottles; heavy clay; few fragments; quartz; few manganiferous nodules.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
†B0.10	7.2	.05	.002																
0.10	7.0	.04	.001	5	19	17	58	34	15	11	.75	.15	2.2	.018	.03	.19	30	15	.60
0.20	7.3	.07	.004																
0.30	7.5	.19	.021	5	18	17	60	33	16	12	2.6	.05	7.9	.015	.02	.014	35	16	.75
0.60	5.1	.90	.100	5	18	16	60	29	9.1	7.0	4.0	.03	13.8	.014	.02	.051	37	17	.65
1.20	4.5	1.3	.137	3	16	19	60	27	9.5	7.3	4.0	.04	14.8	.010	.02	.038			

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K		DTPA-extr (mg/kg)		
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
†B0.10			12	6		19	30	1.1	0.3
0.10	0.5	0.03	11	6	17				
0.20	0.5	0.03	11	5	28				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

† refers to the bulking of a number of surface samples from a cultivated paddock prior to analysis

17. SPRINGTON

REPRESENTATIVE PROFILE

AMU: SPRINTON

SITE: ATE 2

AMG REFERENCE: 642 400 mE 7 358 000 mN ZONE 55

GREAT SOIL GROUP: Brown clay

PRINCIPAL PROFILE FORM: Ug 5.32

AUSTRALIAN SOIL CLASSIFICATION: Calcareous, self-mulching, brown vertosol

SUBSTRATE MATERIAL: Sandstone

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1%

LANDFORM ELEMENT TYPE:

LANDFORM PATTERN TYPE: Plain

VEGETATION

STRUCTURAL FORM: Woodland

DOMINANT SPECIES: *Terminalia oblongata, Geijera parviflora, Acacia harpophylla, Eremphila mitchellii, Canthium oleifolium*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY:

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.10 m	Dark brown (7.5YR 3/3) moist; medium clay; moderate <2 mm granular; moderately weak; few carbonate nodules, moderately calcareous.
B2	0.10 to 0.80 m	Dark brown (7.5YR 3/4) moist; medium clay; few fragments, quartz; moderately firm; few carbonate nodules, moderately calcareous.
D	0.80 to 0.85 m	Brown (7.5YR 4/4) moist; sandy clay; many fragments, quartz; moderately weak; many carbonate nodules, very highly calcareous.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33’	1500’	Ratio
0.10	8.2	.11	.002	36	18	5	38	31	23	7.5	<.10	.19	<.3	.035	.11	.015	28	15	.34
0.30	8.6	.10	.001	36	18	6	38	33	24	8.4	.13	.08	.4	.029	.08	.013	30	17	.40
0.60	8.7	.10	.001	35	19	7	37	32	21	11	.32	.08	1.0	.031	.07	.013	30	16	.43
0.85	8.6	.19	.010	32	30	14	21	59	34	23	1.2	. 10	2.0	.069	.33	.015	42	22	.63

Depth (m)	Org. C (%)	Tot. N (%)	Extr. P (mg/kg) Acid	Extr. P (mg/kg) Bicarb.	Extractable K (meq %)	DTPA-extr (mg/kg) Fe	Mn	Cu	Zn
0.10	0.8	0.08	28	10	0.20	11	9	1.3	2.1
0.20	0.6	0.05	28	6	0.11				

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

18. TURKEY CREEK

REPRESENTATIVE PROFILE

AMU: TURKEY CREEK

SITE: EME 51

AMG REFERENCE: 643 800 mE 7 359 900 mN ZONE 55

GREAT SOIL GROUP:

PRINCIPAL PROFILE FORM: Dd 3.13

AUSTRALIAN SOIL CLASSIFICATION: Vertic, hypercalcic, grey vertosol

SUBSTRATE MATERIAL:

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 0%

LANDFORM ELEMENT TYPE: Flat

LANDFORM PATTERN TYPE: Level Plain

VEGETATION
STRUCTURAL FORM: Woodland
DOMINANT SPECIES: *Eucalyptus cambageana, Casuarina cristata, Acacia harpophylla, Geijera parviflora, Eremophila mitchellii*

PROFILE MORPHLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Few medium pebbles, subrounded unspecified coarse fragments; no microrelief.

HORIZON	DEPTH	DESCRIPTION
A1	0 to 0.05 m	Brown (7.5YR 4/3) moist; sandy clay loam; weak granular; dry loose. Abrupt to:
B21	0.05 to 0.25 m	Brownish black (7.5YR 3/2) moist; medium clay; few small pebbles, subrounded quartz; strong 2-5 mm prismatic; dry; moderately strong. Gradual to:
B22	0.25 to 1.40 m	Greyish brown (7.5YR 4/2) moist; few medium distinct dark mottles, very few medium distinct yellow mottles; heavy clay; few small pebbles, subrounded quartz; strong lenticular; dry; moderately strong; few medium carbonate nodules, very few coarse carbonate nodules, few medium carbonate soft segregations, few fine manganiferous nodules.

				Particle Size (%)				Exch. Cations (m.eo/100g)						Total Elements (%)			Moisture (%)		Disp.
Depth (m)	pH	EC (dS/m)	Cl (%)	CS	FS	S	C	CEC	Ca	Mg	Na	K	ESP	P	K	S	33'	1500'	Ratio
0.10	8.6	.11	.001	35	27	10	32	26	21	5.3	.23	.30	0.9	.028	.079	.024		11	.26
0.40	8.9	.15	.001	28	17	9	47	39	24	15	1.4	.08	3.6	.012	.031	.015		19	.54
0.70	9.3	.23	.003	33	19	8	41	34	15	16	2.6	.07	7.6	.010	.018	.025		16	.52
1.00	9.3	.33	.013	28	18	10	46	37	15	19	3.5	.08	9.5	.011	.033	.022		28	.62
1.10	9.1	.53	.039	22	19	11	47	37	13	20	4.0	.09	10.8	.012	.024	.023			
1.20	8.8	.69	.063																
1.40	8.6	.55	.059																
1.50	9.0	.48	.055																

Depth	Org. C	Tot. N	Extr. P (mg/kg)		Extractable K	DTPA-extr (mg/kg)			
(m)	(%)	(%)	Acid	Bicarb.	(meq %)	Fe	Mn	Cu	Zn
0.10	1.0	0.11	16	8	0.28	10	10	0.5	0.3

* - 33kPa (-0 33 bar) amd -1500kPa (-15 bar) using pressure plate apparatus

Ratings used for interpretation of soil analyses

Appendix IV

			Ratings			
Soil Test	**Units**	**Very Low**	**Low**	**Medium**	**High**	**Very high**
EC	(dS/m)	< 0.15	0.15-0.45	0.45-0.90	0.90-2.0	> 2.0
Cl	(%)	< 0.01	0.01-0.03	0.03-0.06	0.06-0.20	> 0.20
P_A	(mg/kg)	< 10	10-20	20-40	40-100	> 100
P_B	(mg/kg)	< 10	10-20	20-40	40-100	> 100
Extr. K	(m. eq%)	< 0.1	0.1-0.2	0.2-0.5	0.5-1.0	> 1.0
Cu	(mg/kg)	< 0.1	0.1-0.3	0.3-5	5-15	> 15
Zn pH>7	(mg/kg)	< o.3	0.3-0.8	0.8-5	5-15	> 15
pH<7	(mg/kg)	< 0.2	0.2-0.5	0.5-5	5-15	> 15
Mn	(mg/kg)	< 1	1-2	2-50	50-500	> 500
Total N	(%)	< 0.05	0.05-0.15	0.15-0.25	0.25-0.5	> 0.5
Total P	(%)	< 0.005	0.005-0.02	0.02-0.05	0.05-0.10	> 0.10
Total K	(%)	< 0.1	0.1-0.5	0.5-1.0	1.0-3.0	< 3.0
Total S	(%)	< 0.005	0.005-0.02	0.02-0.05	0.05-0.10	> 0.10
PAWC	(%)	< 5	5.1-8.0	8.1-12	12.1-15	> 15
Dispersion ratio			0.6	0.6-0.8	> 0.8	

Source: Bruce and Rayment, 1982 (chemical analyses) Reid et al, 1979 (physical analyses)

Glossary

A horizon	See *Soil horizon.*
A_2 horizon	See *Subsurface soil; Bleach.*
Acid clay	Clay subsoils of low pH that occur under brigalow-belah vegetation
Acid soil	A soil giving an acid reaction throughout most or all of the soil profile (precisely, below a pH of 7.0; practically, below a pH of 6.5). Generally speaking, when the pH drops below 5.5 the following specific problems may occur - aluminium toxicity, manganese toxicity, calcium deficiency and/or molybdenum deficiency. Such problems adversely affect plant growth and root nodulation, which may result in a decline in plant cover and increase in erosion hazard. See *pH.*
Acid volcanic rocks	See *Volcanic rocks, acid.*
AE	Adult Equivalent - represents a 450 kg live weight, non-lactating bovine.
Aeolian sediments	See *sedimentary rocks.*
Alkaline soil	A soil giving an alkaline reaction throughout most or all of the soil profile (precisely, above a pH of 7.0; practically, above a pH of 8.0). Many alkaline soils have a high pH indicated by the presence of calcium carbonate, and are suitable for agriculture. However, others are problem soils because of salinity and/or sodicity. Soils with a pH above 9.5 are generally unsuitable for agriculture. See *pH.*
Alluvial plain	A plain formed by the accumulation of alluvium on a floodplain over a considerable period of time; this accumulation may be still occurring at present (recent alluvium) or may have ceased (relict alluvium).
Alluvium (pl. alluvia)	Deposits of gravel, sand, silt, clay or other debris, moved by streams from higher to lower ground.
B horizon	See *Soil horizon.*
Backplain	Large alluvial flat occurring some distance from the stream channel; often characterised by a high water table and the presence of swamps or lakes.
Basalt	See *Volcanic rocks.*

Bleach	Subsurface soil (A_2 horizon) that is white, near white or much paler than adjacent soil layers. It occurs in varying proportions:
	conspicuous bleach - 80% or more of the layer is white or almost so, when the soil is dry.
	sporadic bleach - the bleaching occurs irregularly through the suburface layer, or as blotches or, as nests of bleached grains of soil material often at the interface of the surface and subsoil layers.
C material	Layer(s) below the B horizon which may be weathered parent material, not bedrock, little affected by soil-forming processes.
Clays	Soils with a uniform clay texture throughout the surface soil and subsoil.
• *cracking*	Clay soils that develop vertical cracks when dry.
• *non-cracking*	Clay soils that do not develop vertical cracks when dry.
Colluvium *(pl. colluvia)*	Slope deposits of soil and rock material.
Colour	See *Soil colour*
Concretion *(in soil)*	Rounded mineral aggregate.
Consistence	Refers to the degree of resistance to breaking or deformation when a force is applied.
Cracking clays	See *Clays, cracking.*
Deep weathering	The process by which earthy or rocky materials are slowly broken down into finer particles and soil by chemical and physical processes over a long period of time.
Dispersion *(dispersivity)*	The process whereby soils break down and separate into their constituent particles (clay, silt, sand) in water.
Dissection	The process of streams or erosion cutting the land into hill, ridges and flat areas.

Drainage
(soil profile)

The rate of downward movement of water through the soil, governed by both soil and site characteristics. Categories are as follows:

Very poorly drained: free water remains at or near the surface for most of the year.

Poorly drained: all soil horizons remain wet for several months each year.

Imperfectly drained: some soil horizons remain wet for periods of several weeks.

Moderately well drained: some soil horizons remain wet for a week after water addition.

Well drained: no horizon remains wet for more than a few hours after water addition.

Rapidly drained: no horizon remains wet except shortly after water addition.

Duplex soil

A soil in which there is a sharp change in soil texture between the A and B horizons (surface and subsoil) over a distance of 10 cm or less. Also known as texture-contrast soil.

Duricrust

A cemented layer at or near the surface resulting from concentration of breakdown products of rock weathering.

Earths

Soils with a sandy to loamy (including clay loam) surface soil gradually increasing to a loamy to light clay subsoil.

- *massive*

Earths in which the subsoil is not arranged into natural soil aggregates and appears as a coherent, or solid mass.

- *structured*

Earths in which the subsoil is arranged into natural soil aggregates which can be clearly seen.

Effective rooting depth (ERD)

Depth to which most plant feeder roots will penetrate. This is taken here to be the depth either to which salts have been leached and have therefore accumulated, or to an impeding layer. This represents the long-term depth of wetting.

Erodibility
(soil)

The suscepitibility of a soil to the detachment and transportation of soil particles by erosive agents. It is a function of the mechanical, chemical and physical characteristics of the soil, and is independent of the other factors influencing soil erosion such as topography, land use, rainfall intensity and plant cover. It may be changed by management.

Erosion hazard The susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform, soil, land use and land management factors.

ESP Exchangeable sodium percentage. *See sodicity*.

Gilgai Surface microrelief assoiciated with soils containing shrink-swell clays. Characterised by the presence of mounds and depressions.

- *linear* Long, narrow, parallel, elongate mounds and broader, elongate depressions more or less at right angles to the contour; usually in sloping lands.

- *melonhole* Large depressions, usually greater than 3 m diameter and deeper than 0.4m, which have a sub-circular or irregular shape and are separated by elongate mounds or set in an almost level surface.

- *normal* Small, irregularly distributed mounds and sub-circular depressions, usually with less than 0.4 m vertical interval between the mound tops and bottom of depressions.

Gley Grey, blue and green coloured clay subsoil (B horizon). Caused by poor drainage which reduces iron and other elements.

Granite/granitic rocks Coarse-grained, *igneous* rock formed well below the Earth's surface in which quartz constitutes up to 50% of the minerals. Other minerals included are felspars and micas.

Hard setting Surface soil that becomes hard and apparently structureless on the periodic drying of the soil.

Horizon See *Soil horizon*, also *Soil horizon boundary*.

Igneous rocks Rock crystallised from molten rock material (magma). It may be extruded to the Earth's surface (*volcanic*) or cool at variable depths below the surface (intrusive, and plutonic).

Intermediate volcanic rocks — See *Volcanic rocks, intermediate.*

Kaolinisation — Breakdown of minerals (particularly feldspars) under intense weathering to form kaolinite clay (china clay). See also ***Laterite.***

Laterite — A profile formed by intense weathering. Many deeply weathered profiles termed 'lateritic' exhibit a distinct series of layers including a surface duricrust, ironstone and mottled and pallid (kaolinised) zones. The word laterite is used for any profile in which ironstone is a major feature. See *Duricrust.*

Lateritised rocks — Rocks which have been partially or completely weathered to laterite

Levee — A very long, very low, nearly level ridge immediately adjacent to a stream channel, built up by over-bank flow.

Lithology — The character of a rock type, such as its colour, mineral composition and grain or crystal size.

Loams — Soils with a uniform loam (including clay loam) texture throughout the surface soil and subsoil. See also *Soil texture.*

Local relief — The altitude difference between the base and crest of slopes in undulating or hilly areas.

Mangans — Coatings of managanese oxides or hydroxides on surfaces of natural soil aggregates. The material may have a glazed appearance and is very dark brown or black.

Massive earths — See *Earths, massive.*

Massive structure — See *Soil structure, apedal.*

Metamorphic rocks — Rocks that were originally igneous or sedimentary that have been physically and / or chemically altered by high temperatures and / or pressures beneath the Earth's surface.

Mottle — Spots, blotches or streaks of subdominant colours different from the main soil colour.

Nodules *(in soil)* — Irregular rounded mineral aggregates.

Non-calcic brown soil — Soils with strong texture contrast between A horizons and B horizons which are not strongly acid and are non sodic. The dominant colour of the upper part of the B horizon is brown.

Non-cracking clays — See *Clays, non-cracking*.

Permeability — The capacity for transmission under gravity of water through soil or sediments.

Plant available water capacity (PAWC) — The quantity of water held in a soil that can be extracted by plant roots.

pH — A measure of the acidity or alkalinity of a soil. A pH of 7.0 indicates neutrality, higher values indicate alkalinity and lower values indicate acidity. Each unit change in pH represents a 10-fold change in either the acidity or alkalinity of the soil. For example, a pH of 5.0 is 10 times more acid than a pH of 6.0.

Soil pH affects the amount of different nutrients that are soluble in water and therefore the amount of nutrient available to plants.

Red-brown earth — Soils with strong texture contrasts between A horizons and sodic or non sodic B horizons which are not strongly acid. The dominant colour of the upper part of the B horizon is red.

Relict landform — A land surface feature created by processes no longer operating in that place.

Salinity — The presence of sufficient soluble salts to adversely affect plant growth and/or land use. The main salt involved is sodium chloride, but sulphates, carbonates and magnesium salts occur in some soils. It is expressed as a level of electrical conductivity (EC).

Sands — Soils with a uniform sand (including sandy loam) texture throughout the surface soil and subsoil.

Secondary salinity — Salinity resulting from man's activities, largely through land development. See *Salinity*.

Sedimentary rocks — Rocks formed from the accumulation of material which has been weathered and eroded from pre-existing rocks, then transported and deposited as sediment by wind (aeolian) or water (fluvial, marine).

Sedimentary rocks have been classified according to grain size and constituent minerals:

Sedimentary rocks

- Clay-sized grains **Mudstone**
- Silt-sized grains **Siltstone**
- Sand-sized grains **Sandstone**
- Gravel-sized grains **Conglomerate**

Sandstone is further subdivided on the basis of the dominant minerals making up the clasts (solid inclusions) or the matrix which cements the clasts together:

Sandstone

- 90% or more of grains are quartz: **Quartzose sandstone**
- less than 75% of grains are quartz: **Labile sandstone**

Segregation Discrete accumulations in the soil because of the concentration of some constituent, usually by chemical or biological action.

Self-mulching A condition of well-structured surface soil, notably of clays, in which the aggregates fall apart naturally as the soil dries to form a loose mulch of soil aggregates.

In cultivated soils, ploughing when wet may appear to destroy the surface mulch which, however, will re-form upon drying.

Snuffy *(surface soil)* Soils with a surface having a very fine granular structure and a dry consistence strength that is weak to very weak. The soil may be water repellent and becomes powdery when cultivated.

Sodicity A characteristic of soils (usually subsoils) containing exchangeable sodium to the extent of adversely affecting soil stability, plant growth and / or land use. It is measured as a percentage of the cation exchange capacity of the soil.

The classes are defined as follows:

non-sodic - less than 6%
sodic - between 6% and 15%
strongly sodic - more than 15%

Sodic or strongly sodic soils would by dispersible and may be improved by the addition of gypsum.

Soft segregations *(in soil)* — Soft, finely divided mineral compounds accumulated in the soil through chemical action with water. They are not easily separated as discrete bodies (compare with *Nodules*)

Soil colour — The colour of soil material is determined by comparison with a standard Munsell soil colour chart. The colour classes used for soil description in this manual are as follows:

Value/Chroma rating*					
Hue	**1**	**2a**	**2b**	**4**	**5**
10R	dark	red-grey	red-brown	red	red
2.5YR	dark	grey-brown	red-brown	red	red
5YR	dark	grey-brown	brown	red-brown	red-brown
7.5YR	dark	grey-brown	brown	yellow-brown	brown
10YR	dark	grey	yellow- brown	yellow	brown
2.5YR	dark	grey	yellow-grey	yellow	olive-brown
5Y	dark	grey	yellow-grey	yellow	olive

*Value/Chroma rating is that defined by Northcote (1979)
Value/Chroma 2a = 4/1, 4/2 to 6/1, 6/2
Value/Chroma 2b = 5/3, 5/4 to 6/3, 6/4

Actual Munsell names were used for colours with a value/chroma rating of 3.

Soil horizon — A layer of soil material within the *soil profile* with distinct characteristics and properties produced by soil-forming processes, and which are different from those of the layers above and / or below. The three main horizons are: A (topsoil); B (subsoil); C (see C material).

Soil horizon boundary — Boundaries between horizons take many forms. The terms used are:

Sharp - less than 5 mm wide; **Abrupt** - 5 to 20 mm wide;

Clear - 20 to 50 mm wide; **Gradual** - 50 to 100 mm wide;

Diffuse - more than 100 mm wide.

Soil profile — A vertical cross-sectional exposure of a soil, from the surface to the parent material or *substrate.*

Soil reaction trend — The general direction of the change in pH with depth.

Soil structure — The arrangement of natural soil aggregates that occur in soil; structure includes the distinctness, size and shape of these aggregates.

- *strong* — The natural soil aggregates are quite distinct in undisplaced soil; when displaced more than two-thirds of the soil material consists of aggregates (ie. well structured).
- *moderate* — Natural soil aggregates are well formed and evident but not distinct in undisplaced soil; when displaced more than one-third of the soil material consists of aggregates (ie. moderately structured).
- *weak* — The natural soil aggregates are are indistinct and barely observable in undisplaced soil; when displaced more than one-third of the soil material consists of aggregates (ie. moderately structured)
- *coarse* — The natural soil aggregates are relatively large; an average size of 20 mm or more is coarse for the purpose of this manual.
- *medium* — The average size of the natural soil aggregates is between fine and coarse.
- *fine* — The natural soil aggregates are relatively small; an average size of 5 mm or less is fine for the purposes of this manual.

- *apedal* — There are no observable natural soil aggregates (structureless); the soil may be either a coherent mass (massive) or a loose, incoherent mass of individual particles such as sand grains (single grain).
- *blocky* — The natural soil aggregates have the approximate shape of cubes with flat and slightly rounded sides.
- *prismatic* — The natural soil aggregates have the approximate shape of elongated blocks.
- *columnar* — The natural soil aggregates are like those of prismatic but have domed tops.
- *polyhedral* — The natural soil aggregates are irregular, many sided and multi-angled.
- *lenticular* — The natural soil aggregates are like large vertical lens shapes with curved cracks between the aggregates.

Soil texture — The coarseness or fineness of soil material as it affects the behaviour of a moist ball of soil when pressed between the thumb and forefinger. It is generally related to the proportion of clay, silt and sand within a soil. Texture classes used in this manual are defined primarily by the total clay content:

	Group	**Clay content (%)**
Coarse	Sand Loamy sand Sandy loam	less than 5 5 to 10 10 to 20
Medium	Loam Sandy clay loam Clay loam	~ 25 20 to 30 + sand 20 tp 35
Fine	Sandy clay Light clay Medium clay Heavy clay	35 to 40 + sand 35 to 40 40 to 50 more than 50

Solodic Soils Soils with strong texture contrast between A horizons and sodic B horizons which are not strongly acid.

Structured earths *See* Earths, *structured.*

Subsoil Soil layers below the surface with one of the following attributes:

- a larger content of clay, iron, aluminium, organic material (or several of these) than the surface and subsurface soil;
- stronger colours than those of the surface and subsurface soil above, or the *substrate* below. The B horizon.

Substrate The material below the soil profile which may be the parent material or may be unlike the material from which the soil has formed; substrate which is not parent material for the soil above may be layers of older alluvium, rock strata unrelated to the soil or the buried surface of a former landscape.

Subsurface soil Soil layers immediately under the surface soil which usually have less organic matter, paler colours and may have less clay than the surface soil. The A_2 horizon.

Surface soil The soil layer extending from the soil surface down which has some organic matter accumulation and is darker in colour than the underlying soil layers. The A horizon.

Terrace Any long, relatively level or gently sloping surface, generally narrower than a plain and bounded by a steeper ascending slope on one edge and a steeper descending slope on the other. Often associated along the margin and above the level of a body of water eg. stream or lagoon.

Texture See *Soil texture.*

Texture-contrast soil See *Duplex soil.*

Uniform clays See *Clays.*

Uniform loams See *Loams.*

Uniform sands and sandy loams See *Sands.*

Volcanic rocks — Igneous rocks which have cooled from magma extruded to the Earth's surface. The size of the rock crystals depends on its duration of cooling - rapid cooling forms very fine crystals or even volcanic glass.

- *acid* — Contain 10% or more quartz and proportions of magnesium, iron and calcium. Usually light coloured.

- *basic* — Basalt or basaltic rocks containing minimal or no quartz. Usually dark coloured because of a high proportion of iron and manganese minerals.

- *intermediate* — Contain less than 10% quartz and mixed amounts of other minerals that are intermediate between the typical acid and basic igneous rocks.

Waterlogged — An area in which water stands near, at or above the land surface, so that the roots of all plants except those with extreme water tolerance are drowned and the plants die.

Workability — The ease or otherwise of working the soil with machinery.