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Definition

The Sandstone-Yalgoo-Paynes Find area, as described in this report, includes the following 1:250,000 map sheets: Sandstone, Kirkalocka, Youanmi, Ninghan and Barlee, and parts of Yalgoo and Perenjori. The Sandstone-Yalgoo-Paynes Find area contains multiple biogeographic, physiographic and administrative boundaries and as such cannot be recognised as a region in its own right.

National Library of Australia Cataloguing-in-Publication entry

An inventory and condition survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia.

Bibliography
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1. Pastures - Western Australia - Sandstone (W.A.) Region
2. Pastures - Western Australia - Yalgoo (W.A.) Region
3. Pastures - Western Australia - Paynes Find (W.A.) Region
4. Rangelands - Western Australia - Sandstone (W.A.) Region
5. Rangelands - Western Australia - Yalgoo (W.A.) Region
6. Rangelands - Western Australia - Paynes Find (W.A.) Region
I. Payne, A.L. II. Western Australia. Agriculture Western Australia
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Contents

Summary

Scope of the survey

1. The area surveyed by field work during 1992-93 covers about 94,700 km^2 and includes nearly all of the Sandstone, Youanmi, Barlee, Kirkalocka and Ninghan 1:250,000 scale map sheets and parts of the Yalgoo and Perenjori sheets. Three small townships fall within the area, namely Sandstone in the east, Paynes Find in the south-centre and Yalgoo in the west. Apart from a very small portion of the Greenough River catchment in the far north-west there are no major river catchments in the survey area, which is drained internally into the salt lake systems of Lake Barlee, Lake Noondie, Lake Mason, Lake Moore and Mongers Lake.

2. Pastoralism is the most extensive land use in the area. Fifty four pastoral leases fall wholly, and twelve fall partly within the survey area and collectively occupy about 86,460 km^2 (91% of the area). Mining is an important land use which is largely confined to greenstone belts scattered throughout. Areas set aside for nature conservation at the time of survey covered approximately 3,857 km^2 (4.1%) consisting of the previous Mt Elvire pastoral lease and parts of the Mt Manning and Karroun Hill nature reserves. The Department of Conservation and Land Management (CALM) has since purchased the Burnerbinmah pastoral lease which increases the area set aside for conservation to 4,456 km^2 (4.7%).

3. This report provides a regional inventory and descriptive reference of land resources. It includes reviews of land use history, climate, geology and hydrogeology, previous vegetation surveys, declared plants and animals, and native fauna. Detailed accounts are provided of survey methodology, geomorphology, soils, vegetation, ecological assessment, land systems, and resource condition (in terms of pastoral impact) of the survey area. Plant species lists and a land system map are presented as appendices.

4. Resource condition statements are provided for the whole survey area and for each land system. These were derived from more than 9,400 visual traverse assessments, which are shown on the accompanying 1:500,000 scale land system map. Severely degraded and eroded areas were identified and mapped. Quantitative data collected at condition sites was used to analyse the impacts of grazing in four major habitats.

5. The report deals specifically with resource description and assessment, recognising the widespread impact of pastoralism on resources in the process. A companion report[1] focusing on pastoral resources and pastoral management has also been produced, based on the findings of this rangeland survey. Pastoralists are encouraged to refer to both reports.

Land characteristics

6. The climate varies from semi-arid in the south and west to arid in the north-east (mean annual rainfall 230-280 mm). When subjected to analysis, in terms of moisture potential for widespread plant growth, long-term records show the clear predominance of effective winter rainfall (probability 88% throughout), and the highly unreliable nature of effective summer rainfall (25% throughout). A probability-based assessment of rainfall and plant growth provides a basis for long-term strategic planning for pastoralists and other land managers who are operating in a highly erratic and unreliable seasonal environment.

7. Geologically, the area is dominated by a granite-greenstone terrain of the Archaean Yilgarn Block with occasional ranges widely separated by gently sloping pediments, which give way to very gently inclined sheetflood alluvial plains upslope from salt lakes. Drainage is mostly disorganised and internal.

   Soils are mainly shallow, sandy and infertile and, across most of the lower areas, are distinctively underlain by red-brown, siliceous hardpan. Shallow aquifers found extensively below this hardpan and elsewhere have provided most of the groundwaters on which development of the area for pastoral and mining industries has depended. Groundwater consumption by the pastoral industry is small compared with estimated storage. The origins and quality of groundwater were described from survey work conducted by the Geological Survey branch of the Department of Minerals and Energy.

8. Lands within the area have been described and mapped into 20 broad land types comprised of 76 land systems. Eighteen of the systems are described for the first time, the others having been described previously. Their individual extent varies greatly, and almost half the area comprises just

[1]Van Vreeswyk and Godden. (1998). Pastoral resources and their management in the Sandstone-Yalgoo-Paynes Find area, Western Australia. Agriculture Western Australia, Miscellaneous Publication No. 1/98.

seven land systems (Yowie, Carnegie, Bannar, Bullimore, Woodline, Kalli and Joseph). The land system approach is a natural classification of land based on predominant biophysical features. This inventory will be useful for all future land management and land use planning. At a more detailed level, the component land units of each land system are described by their landform features, soils and vegetation associations.

9. The survey area has several natural characteristics that help protect the landscape against inappropriate land use practices. These include widespread stony mantles on pediments; extensive nearly level plains subject to episodic sheet flow with tall shrub strata largely unaffected by grazing; and extensive sandy plains with quite dense tall shrublands. The local areas in which the landscape is most susceptible to degradation are breakaway footslopes, distributary fans and saline alluvial plains.

Soils

10. Twelve broad soil groups (25 soil types) have been identified within the survey area. The most outstanding characteristics of the soils are the predominant red colour and the widespread presence of a siliceous hardpan. Stony mantles and shallowness are also dominant features.

11. The most extensive soils are sands on sandplains and granitic country, and variable depth red earths overlying hardpan on level to gently inclined plains. Lower flood plains have calcareous and saline soils. Duplex, or texture-contrast soils, occur in localised areas in particular on saline alluvial plains and footslopes below granite breakaways or greenstone hills; these soils support the most preferentially grazed vegetation and are highly susceptible to erosion.

Vegetation

12. The flora of the area is diverse. 719 vascular species were recorded in the survey area, of which 706 are native. Twenty-seven of the 66 plant species on the Declared Rare and Priority Flora listing for the survey area were collected. Perennial plant species that have restricted distributions or are rare and endangered are most frequently (though rarely) found on granite and greenstone hills, breakaway plateaux and sandplains.

13. Vegetation associations considered at the scale of the land unit are objectively classified and described as 50 major habitats within 10 broad habitat groups. Ecological assessment is addressed according to habitats, where habitats are an ecological classification based on plant community, soil type and landform. All but three of the habitats are shrublands or low woodlands of which the majority are depauperate in grasses. The most common and abundant genera include *Acacia, Atriplex, Eremophila, Eucalyptus, Maireana, Ptilotus, Senna* and *Stipa*. Cotton bush (*Ptilotus obovatus*), curara (*Acacia tetragonophylla*) and mulga (*A. aneura*) are the most ubiquitous perennials.

14. Intensive sampling of four habitats at 144 condition sites, revealed the patterns of variation that exist, partly through natural variation and partly through impact by grazing animals.

Resource condition

Soil erosion

15. Accelerated soil erosion is widespread but localised, and restricted to a few susceptible vegetation/land unit types. Perennial vegetation on eroded areas is invariably degraded. Erosion problems have evidently started and accelerated primarily as a consequence of loss of perennial vegetation. Natural processes which serve to stabilise otherwise vulnerable soil surfaces have been fragmented or disrupted. Many land units and soil surfaces on stony hills and plains are highly resistant to erosion; others are highly susceptible.

16. Assessments made at more than 9,400 points showed 5.3% had some form of accelerated erosion; moderate erosion was recorded at 1.3% and severe erosion was recorded at 0.4% of the points. The most common forms of erosion were scalding and surface sheeting over 10-50% of the surface. The most susceptible soil types are red duplexes on areas with some slope, which are subject to concentrated sheet flows after rainfall events.

    Eroded areas are mainly plains with patchy vegetation or which are denuded, with deflated or no topsoil and exposed saline subsoils or inert hardpan remaining as the land surface. The preponderance of shallow soils (<50 cm deep over hardpan or baserock) has meant that erosion is not characterised by spectacular gullying.

17. Areas of severe degradation and erosion (sde) larger than 40 hectares were mapped following aerial photo-interpretation and ground verification. The total of these areas was approximately 144.6 km^2,

which represents 0.15% of the survey area. The incidence of sde is largely confined to a small number of susceptible and preferentially grazed land units mainly on Ero, Jundee, Merbla, Monitor, Sherwood, Tindalarra, Wilson and Yalluwin land systems. Wilson and Monitor land systems have the highest proportions (16.3% and 21.5% respectively) of total area mapped as being severely degraded and eroded. Ero, Yalluwin, Merbla and Cunyu are the only other systems with more than 1% of their area mapped as severely degraded and eroded. Fifty-three land systems (out of 76) had no areas mapped as severely degraded and eroded.

Vegetation condition

18. In terms of impact on perennial vegetation by pastoral usage, approximately 23% of traverse records indicated that vegetation was in poor to very poor condition, 32% indicated fair condition and 45% indicated good or very good condition. Taken overall, these summary data show that the vegetation in this survey area is generally in better condition than that recorded from most other regional rangeland surveys in Western Australia.

19. The most frequently observed impacts of pastoralism were loss in perennial species richness and perennial plant density. Decrease in perennial plant cover was only a reliable indicator of grazing impact in chenopod shrublands. This broad type of vegetation is grazed preferentially and generally associated with soils that are susceptible to erosion. Hence, it was in chenopod shrublands that major alterations to vegetation and consequent accelerated soil erosion were most frequently observed. Increases in shrubs well suited to exploiting overgrazed situations was uncommon and they generally did not form dense thickets that might exclude the re-emergence of previous species as has been reported in previous rangeland survey reports (e.g. Payne *et al.* 1987[2]). However, increaser species were observed in chenopod shrublands (*Acacia victoriae, Eremophila lachnocalyx* and *Hakea preissii*), grassy shrublands on the Merbla land system (the exotic *Carthamus lanatus*) and calcareous stony plains (*Senna* spp.).

20. Assessments at which mining impacts were observed were excluded from summaries of resource condition on the basis that condition in this report is primarily concerned with the impacts of grazing on natural resources. Disturbance as a result of mining or mining exploration was recorded at 31 traverse points, which represent 0.32% of traverse assessments and indicates the localised nature of mining impacts.

Management implications and recommendations

21. Within this survey area almost one quarter of the land, currently used for pastoralism, is in poor condition but not severely degraded and eroded. These areas, with mainly intact soil surfaces, present the best prospects for economically feasible perennial vegetation regeneration in the short to medium term.

22. **Areas identified as being severely degraded and eroded should be removed from pastoral use, as continued use will only exacerbate the problem.** Given the generally low economic return per hectare, regeneration of such areas is unlikely to be economically justifiable by pastoralists. Regeneration is also technically difficult and **additional research: to (a) manage total grazing pressure throughout each affected sub-catchment, and (b) to enhance soil accretion and plant establishment on sde areas, is required.** Where regeneration is to be attempted, consideration of catchment and sub-catchment characteristics and processes will improve the chances of success.

23. Numerous land systems, habitats and Declared Rare or Priority Flora species are not represented or are poorly represented on lands set aside for nature conservation within the survey area. **Local community participation** in addressing these deficiencies **is recommended as it is likely to improve the chances of achieving both specific and broad nature conservation goals.** It is unlikely that nature conservation goals will ever be achieved solely within reserved lands. **Acceptance, encouragement, and perhaps compensation and rewarding of local land management participation in activities directly relating to nature conservation is recommended.** This will, to some extent, overcome limited Government resources and inevitable compromises in land use planning at a regional level.

24. The map and contents of this report describe the environment in a spatial context, which is useful for planning future regional conservation strategies or systems of reserves. Resource condition assessments highlight types of land most extensively and severely modified by pastoral land use, and where they exist in a relatively intact state. Furthermore the map, and land system and habitat descriptions are useful for planning ecological monitoring on the basis of representativeness or

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[2]Payne, A.L., Curry, P.J. and Spencer, G.F. (1987). An inventory and condition survey of the Carnarvon Basin, Western Australia. Western Australian Department of Agriculture, Technical Bulletin No. 73.

sensitivity to change. Indeed, the information has already been used to allocate this agency's Western Australian Rangeland Monitoring System sites across the survey area. The map and report also provide essential biological information required for preparing pastoral property development and management plans within the context of sustainable use.

25. It is difficult to evaluate the ecological sustainability of current land management without undertaking exhaustive monitoring of resources and management. On the basis of visual traverse condition assessments, historical resource use has certainly not always been ecologically sustainable. This is particularly apparent in parts of the landscape which supported vegetation preferred by stock on soils susceptible to erosion. In contrast, there have been many assessments of good condition in a variety of landscapes which have been used for pastoralism for decades. This would indicate that, at this broad level, conservative pastoralism can be ecologically sustainable in most land systems.

26. Monitoring is confined largely to measurements of perennial shrub density and size, and soil surface stability. Little monitoring of other ecological aspects such as ephemeral plant dynamics, soil fauna and flora, and native macrofauna, occurs over most of the survey area. However, the Department of Conservation and Land Management has some flora and fauna monitoring sites on reserved lands. At a broader scale, there is also little or no monitoring of landscape processes at a catchment or sub-catchment scale. **Appropriate ecological monitoring systems need to be developed and put in place.**

Introduction

Rangeland surveys

The findings presented in this report are those of a regional survey of lands in the Sandstone-Yalgoo-Paynes Find area. The survey was undertaken by a joint team from Agriculture Western Australia and the Department of Land Administration during 1992 and 1993. This survey is the ninth of its type in a program of arid land classification, mapping and resource evaluation in the State. Other surveys in the program have been undertaken in the Gascoyne River catchment (Wilcox and McKinnon 1972), the West Kimberley (Payne *et al.* 1979), part of the Nullarbor Plain (Mitchell *et al.* 1979), part of the Ashburton River catchment (Payne *et al.* 1982), the Carnarvon Basin (Payne *et al.* 1987), the Roebourne Plains (Payne and Tille 1992), the Murchison River catchment (Curry *et al.* 1994) and the north-eastern Goldfields (Pringle *et al.* 1994).

The survey area

An area of 94,713 km^2 was covered in the Sandstone-Yalgoo-Paynes Find survey which extends from 27°S in the north to 30°S in the south; 115°30'E in the west to 120°E in the east (Figure 1). Two minor river systems are included; the Greenough River in the far north-west and the Warne River near the centre; and ephemeral creeks drain into large salt lakes, the largest of which is Lake Barlee in the south-east. A number of lake systems such as Mongers Lake occur throughout the survey area. In the north the boundaries of the survey were fixed at the limits of coverage achieved by the Wiluna-Meekatharra report (Mabbutt *et al.* 1963) and the Murchison River catchment report (Curry *et al.* 1994), and to the east by the north-eastern Goldfields report (Pringle *et al.* 1994). The northern, southern and eastern limits of the survey area are largely defined by the boundaries of the 1:250,000 map sheets shown in Figure 2. The western limit is the boundary between the pastoral and agricultural area. The survey area includes most of the Yalgoo and Sandstone Land Conservation Districts and part of the Mt Magnet, Murchison, Meekatharra, and Wiluna Land Conservation Districts, and the towns of Yalgoo, Sandstone and Paynes Find. Sixty six leasehold pastoral stations are wholly or partly covered by this survey (Figure 3).

Purpose of the survey

The purpose of the survey was to provide a comprehensive description and maps of the biophysical resources of the region, together with an evaluation of the condition of the soils and vegetation throughout. The report and the accompanying map at 1:500,000 scale are primarily intended as a reference for land managers, land management advisers and land administrators, the people most involved in planning and implementing land management practices. The report and map will also provide researchers and the public with a basic reference on landscape resources of the survey area. The survey inventory also enables the recognition and location of land types with particular land use, habitat or conservation values for land use planning. Maps at other than the published scale can also be generated on request.

Monitoring of vegetation change is well established in the Western Australian rangelands. This report provides the base habitat descriptions necessary for the strategic location of monitoring sites and provides some information for the assessment of resource condition of those habitats.

Contents of the report

The first part of this report provides a brief review of particular aspects of the land use and biophysical features of the survey region. In many instances little detailed information has been published for the region and these chapters draw together the disparate information which is available. The land use history, climate, hydrogeology (provided by the Water and Rivers Commission), regional vegetation, declared plants and animals, and native fauna (provided by the Department of Conservation and Land Management) chapters serve as an introduction to the later more detailed land system, soils, vegetation and ecological assessment chapters. The methodology chapter explains the survey procedure. The geomorphology chapter describes landforms and discusses how they are distributed and formed, and considers land use impacts on the landforms and landscape processes.

The four major chapters within the report discuss the land systems, soils, vegetation and ecological assessment. These chapters provide information on landform, soil and vegetation at the land unit level, and used in conjunction with the map provide a comprehensive inventory of biophysical resources.

The resource condition chapter provides a detailed assessment of land use impacts on the resources of the survey area.

Plant species lists and the land system map comprise the Appendices. The species lists contain information too detailed to include within the main report but provide background information for future research. The 1:500,000 scale land system map is a separate attachment.

A companion report (Van Vreeswyk and Godden 1998), which is directed at the pastoral industry, was prepared using the survey findings. The report provides information which will assist in station management planning. Station reports for each of the pastoral leases within the survey area are presented. Station plans at 1:100,000 showing resource, topographical and infrastructure information were produced and provided to lease holders.

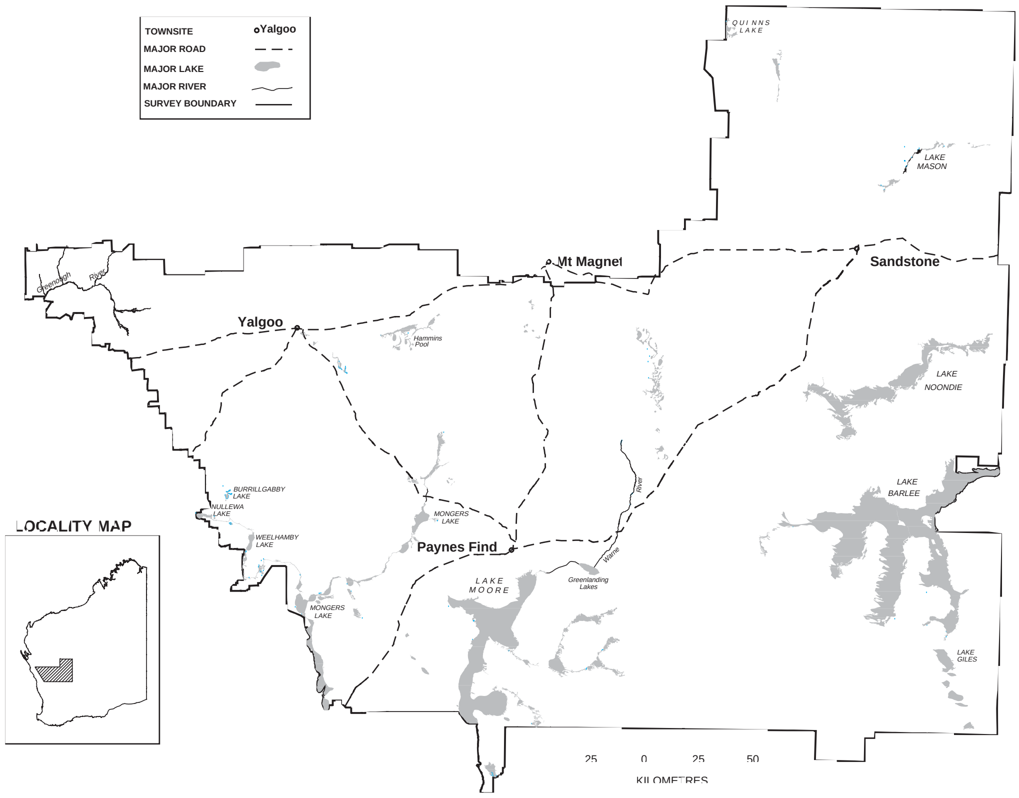

Figure 1. Location map of the Sandstone-Yalgoo-Paynes Find survey area

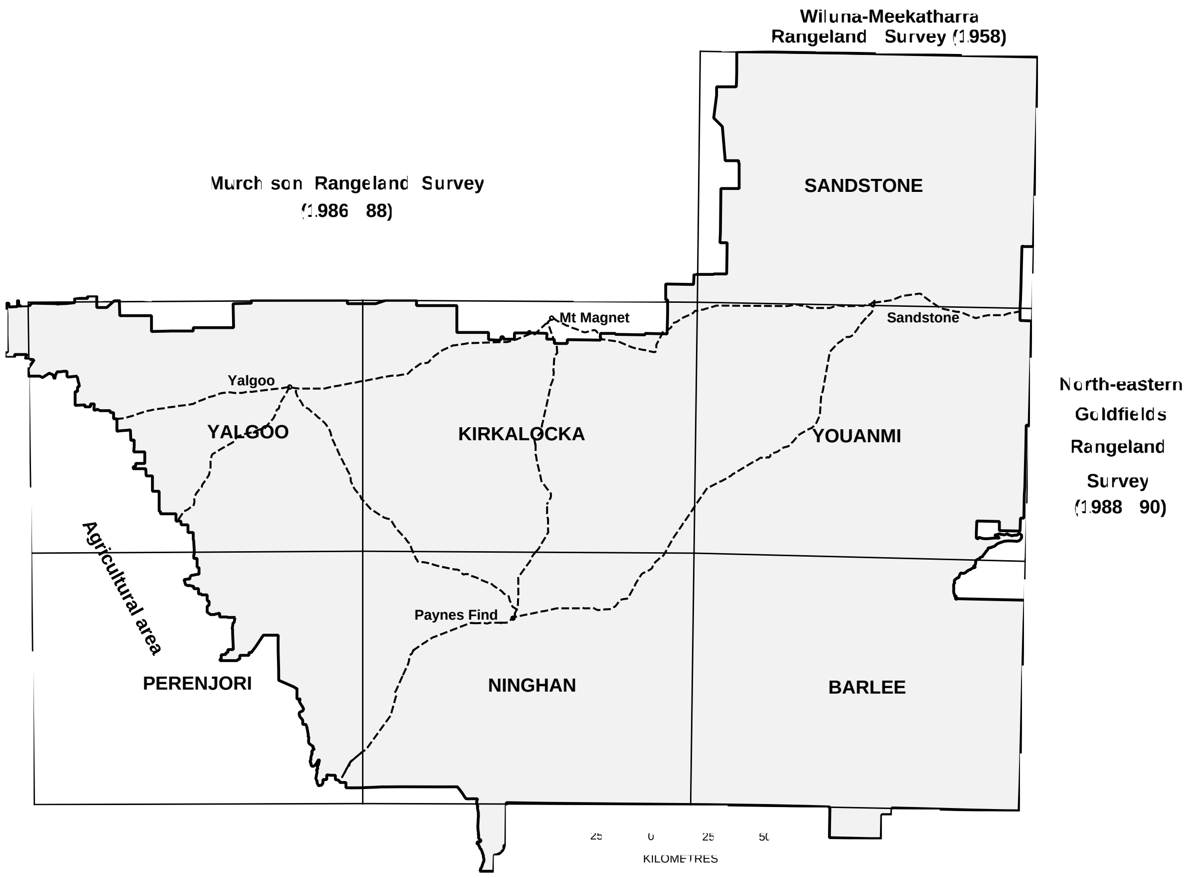

Figure 2. The 1:250,000 map sheets covering the survey area

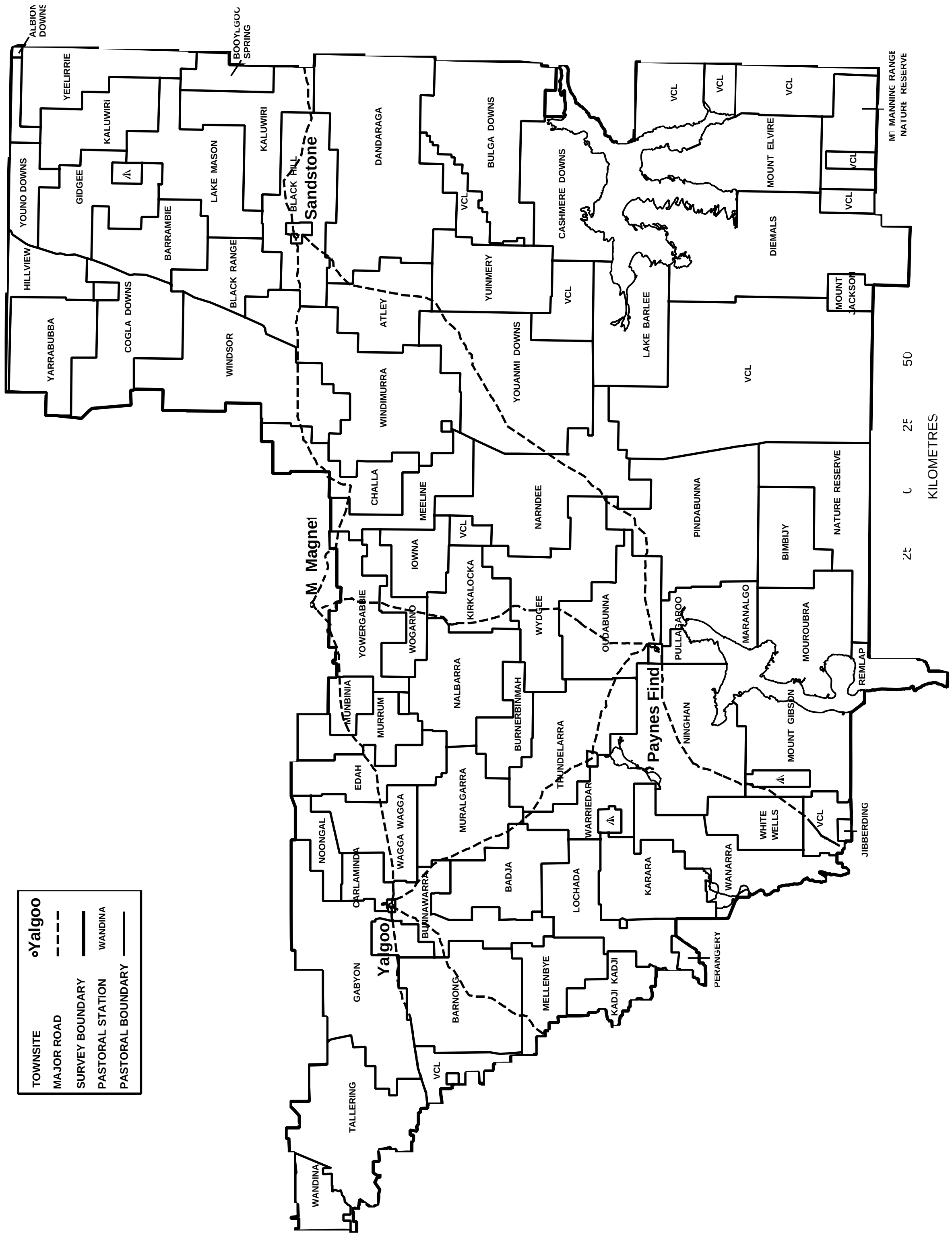

Figure 3. Pastoral stations within the survey area

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Review

A brief land use history (P. Hennig[1])

Climate (K.A. Leighton[2])

Hydrogeology (S. L. Johnson[3])

Regional vegetation (A.M.E. Van Vreeswyk[1])

Declared plants and animals (M. Dowd[4])

Native fauna (A. Chapman[5])

[1]Natural Resource Management Services, Agriculture Western Australia

[2]Land Data Services, Department of Land Administration, Western Australia

[3]Water and Rivers Commission, Western Australia

[4]Production Resource Protection Services, Agriculture Western Australia

[5]Conservation and Land Management, Western Australia

A brief land use history

P. Hennig

Aboriginal occupation

Aboriginal history in Australia dates back at least 40,000 years. Aboriginal peoples in the arid zone lived a nomadic hunter-gatherer life style entirely dependent on climate and native flora and fauna. Their only method of manipulating the environment was through fire. The main Aboriginal groups in the survey area were the Widi tribe, the Barimaia (also spelt Budimaya, Buddiamia or Badimia) tribe, the Kalamaia (or Galamaia) tribe (Tindale 1974), the Yamagee (Yamidji) and the Wongi (Berndt 1979).

The arrival and dominance of European settlers had a dramatic effect on the Aboriginal peoples with the introduction of new diseases, conflict, displacement and lifestyle change. The early colonial government "... gave the Governor the right to grant and dispose of land ..." with the Aboriginal population not being recognised as land owners. However, it was stipulated "... that the Aboriginal people's right of access for the purpose of hunting, fishing and gathering had to be respected by the (pastoral) lessees ..." (Webb 1993). Burnside (1993) states European settlers considered "the resources of the arid environment as exclusively available for exploitation".

Webb (1993) suggests European pastoral occupation was, in general, peaceable and unopposed, but some clashes did occur. In 1881, Aborigines took possession of 2,000 sheep near Mt Kenneth (Wydgee station) while the stockmen were barricaded in a hut for two days. Only 700 sheep were recovered (Palmer 1988).

Aborigines were often used as guides by early exploration parties and with the establishment of pastoral properties, employed as station workers or stockmen, often in exchange for food, accommodation or little money. Large Aboriginal station labour forces (up to eight) were common to the late 1960s when families of the labourers also lived on the station (Blood personal communication). Now, very few families or labourers are employed due to the introduction of the basic minimum wage in 1966 and the generally poor economic circumstance of the industry. Nearly all Aboriginal families currently live in towns in the area. Very few if any Aboriginal people live traditional lifestyles in this survey area.

One station in the survey area is currently occupied by Aboriginal groups. It is unclear what impact the Native Title Act (1992) will have on land tenure and land rights in the survey area.

Early exploration

After the establishment of the Swan River Colony much of the land around the settlement, the south-west and the coastal margin was taken up, mainly for agriculture. The need for the colony to expand and develop more land for agricultural production encouraged expeditions into the unknown inland.

The first major expedition to the vicinity of the present survey area was led by Augustus Charles Gregory in 1846 (see Figure 1). From Goomalling the team ventured north-east into the survey area to what is now Mt Jackson, then to Mt Churchman (Mouroubra station), Mt Singleton (known as Ninghan to the local Aborigines), passing just north of the present Paynes Find townsite to Gnows Nest Range, south of the present day Yalgoo. The explorers returned south via the Irwin district toward the coast, south of Geraldton.

In 1854 Assistant Surveyor Robert Austin led an exploration party from near present day Northam to Mt Marshall, Mt Churchman and Lake Moore. Further north he named Mt Kenneth, passing Mt Magnet then moving north and west to the Sanford River. (Austin suggested, the land in the vicinity of Mt Magnet was "...probably one of the finest Goldfields in the world...') Nathaniel William Cooke, after taking up 4,000 acres in the Irwin district, explored out to Gullewa (Barnong station) and Yalgoo in 1862. (Cooke went on to discover gold at Marble Bar and Nullagine, and copper at Whim Creek.)

In 1868 J.H. and G. Monger travelled from York to Mt Singleton, and Goodenow (or Goodingnow south of Paynes Find), returning to York via Mt Singleton and Damperwah (Karara station). The following year John Forrest (a surveyor who became the first Premier of Western Australia) led another expedition into the area. Covering Mt Churchman, Lake Moore, the Warne River (Pindabunna station), Lake Barlee and land now covered by Pullagaroo, Oudabunna, Ninghan and Karara stations, Forrest's brief was to investigate the fate of Ludwig Leichhardt's exploration team missing in Central Australia. He indicated that the Sandstone area might be gold-bearing but was unsuitable for pastoralism.

In 1900 H.G.B. (Harry) Mason led an expedition east of Cue to Black Range, Booylgoo Range, Lake Carnegie and the South Australian border.

Early pastoral settlement

Considering the first export shipment of sandalwood from the south-west of the colony was in 1845 (Western Australian Year Book 1902-4) it is most likely that sandalwood cutters were the earliest residents in the central region. Pastoralists then prospectors followed the paths of the cutters ultimately turning tracks into established travelling routes. The first pastoral leases in this area were granted in the mid to late 1860s as up to 4,000 hectare lots. Many parcels of pastoral land were taken up in the early to mid-1870s on explorers' recommendations. For example, Palmer (1989) noted Forrest's second major expedition to the Murchison area in 1873 passed through a number of embryonic pastoral holdings such as Barnong, Wurarga (about 35 km west of Yalgoo) and Mungarra (Gabyon). Land around waterholes or natural springs was taken up first. Some shepherds grazed livestock along water courses until they found suitable land. Sometimes, only when under threat of losing a claim, did squatters apply for leasehold land. Fencing in the early years was usually confined to holding paddocks as livestock were mainly shepherded. In 1874 E. Wittenoom carved out the first wool road from the Murchison towards Geraldton. 'Changing stations' such as Nannowtharra (Wagga Wagga station), Munbinia and Chain Pump (near Yalgoo) were set up along various routes, providing travellers with information on what lay ahead and opportunities to rest or change horses (Palmer 1993). These blocks were very small and later absorbed into larger properties.

The size of pastoral properties varied greatly. Some original

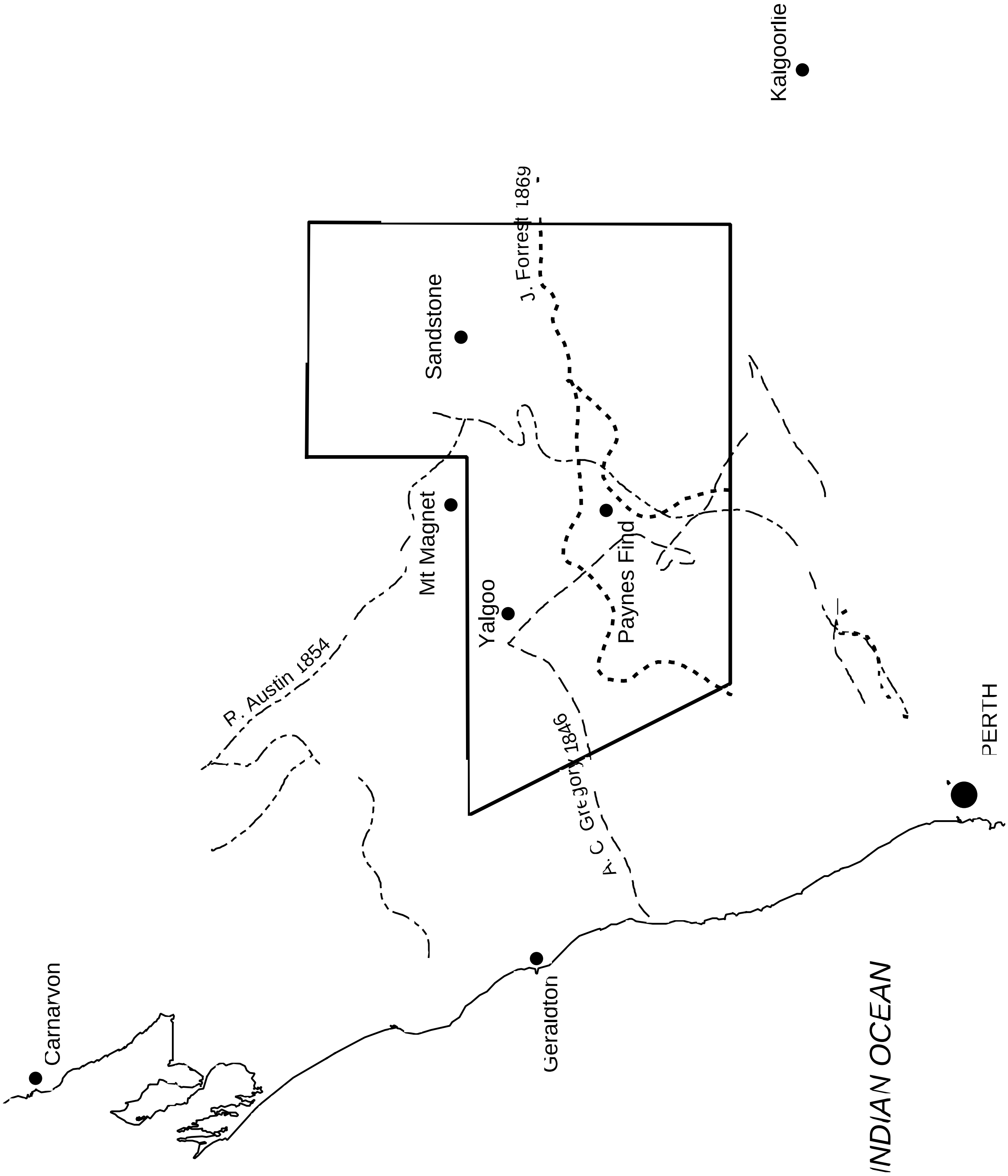

Figure 1. Early exploration routes

leases were as small as 800 hectares, perhaps indicating inflated early expectations of the land. Pastoral leases were frequently transferred or amalgamated to the extent that one present day property is made up of 19 original leases (Palmer 1989). Amalgamation followed more intense development of station infrastructure (yards, fences, etc.) with good quality water provided by relatively shallow wells.

Land adjoining mining centres was often taken up to supply the new settlements with meat. Livestock was originally brought in from agricultural areas and grazed until required for slaughter. Boogardie station (adjacent to Mt Magnet), established in 1880, for example, was noted to "become most important in supplying water and meat to the future adjacent gold mining centres" (Day and Morrissey 1995).

Below is a list of some of the earliest settled properties in the survey area with original lessees and year of establishment.

Goodingnow	D. MacPherson	1872
Gullewa Spring (Barnong)	M. Morrissey	1872
Pinyalling Spring (Thundelarra)	C.A. Fane	1873
Budja Spring (Badja)	M. Morrissey	1873
Bunnawarra	M. Morrissey	1873
Carlaminda (North-east)	M. Morrissey	1873
Maranalgo	D. MacPherson	1873
Mugga Mugga Hill (Barnong)	Waldeck and Maley	1873
Mungarra (Gabyon)	Howard and Shenton	1873
Nangagetty Spring (Thundelarra)	N. & H. Cooke	1873
Oudabunna	D. MacPherson (?)	early 1870s?
Warra Warra (Gabyon)	A.G. Lacy	1873/74
Ninghan	N. & H. Cooke	mid 1870s ?
Burnerbinmah	J. Morrissey	1878
Mt Gibson	G. & H. Foss	1878
Dalgaranga	A.G. Lacy	1878
Edah J. Smith		1878
Yoweragabbie	J. Watson	1878
Carlaminda (Homestead block)	A.G. Lacy	1879
Budja Spring (Muralgarra)	S.L. Burgess	about 1879
Budado Spring (Bunnawarra)	W.F. Waldeck	1879
Challa G.C. Dowden		early 1880s
Mt Gibson	N. Cooke	1880
Murrum	J. Fitzgerald	about 1880
Pindabunna	C. & H. Foss	1880
Wagga Wagga	J. Morrissey	1881
Mellenbye	H. & J. Broad	1881
Warriedar (part)	F. Wittenoom	1900
Warriedar (part)	T. & S. Oliver	1908
Wydgee	G. & E. Oliver	1882
Carlaminda (Yalgoo block)	Fitzgerald and Stevens	1882
Warracootharra (Windimurra)	J.W. Waldeck	1888
Weradjaminda (Bunnawarra)	P.M. Morrissey	1894
Warriedar	F. Wittenoom	1900
Perangery	W.H. Herbert	1905

(List compiled from Day and Morrissey 1995, Palmer, 1988-89 and Senior 1995.)

"... The worst things were cutting curara or standback bushes, as the stiff spines and thorns showered out with every blow of the axe penetrating their clothes and irritating the skin until often there were raw sores which developed into Barcoo rot..."
(A comment from settlers clearing land on the south-west survey margin. Cannon 1983.)

Expansion through discovery of gold

Surprisingly, there is no official record of who first discovered gold in the Yalgoo district unlike the recognition given to Paddy Hannan, who discovered gold at Kalgoorlie. Perhaps the Yalgoo discovery was kept quiet to prevent immediate competition.

It is believed that a team of five prospectors (who encountered Aboriginal children playing with gold-rich rocks) or an Aboriginal shepherdess discovered the Emerald Reef gold deposit in late 1892 at the site of present day Yalgoo (Palmer 1989). The resulting rush established Yalgoo as a town in 1893 with many businesses and prospectors.

The name Yalgoo is Aboriginal and believed to mean 'meeting place'. Other Aboriginal derivations are: Yagoo (an initiate's tribal tutor); Yalgo (meaning blood); and Yalguru (a prickly acacia tree, significant in initiation legend).

In 1894 G. Woodley discovered gold at Rothesay about 16 km west of the Damperwah Hills and Springs (part of the

1869 Forrest expedition route) thus creating interest in the Perenjori area (Cannon 1983). Many new finds were made and by 1895 the Western Australian Government proclaimed the Yalgoo Goldfield.

By 1898-99 telegraph communications had been set up at Yalgoo, the Mullewa-Cue railway (via Yalgoo and Mt Magnet) was completed, while Rothesay's population had increased to 300 and Yalgoo to 400.

With the establishment of gold mining centres at Cue in the Murchison and the Mt Margaret Goldfield to the east, prospectors passed through the Black Range (Sandstone) area. It was noted for lack of water so many failed to prospect even though the land appeared to have potential. In 1894 a group of six led by Ernest Shillington discovered gold where the town of Nungarra was later sited. Although other prospectors claimed to have found gold in the Black Range beforehand, Shillington's team were the first to register a claim in early 1895. With this claim, prospectors came to the Black Range. In 1896, Thomas Payne a prospector from Gullewa (Barnong station), discovered gold about 90 km from Sandstone. This place was later named Youanmi.

Around the turn of the century, the area experienced its first of many boom-bust cycles. A general recession hit the local mining economy hard. Many gold operations around Yalgoo ceased due to dwindling alluvial gold and the town's main focus was the pastoral industry despite a couple of drought years. By 1902 the Rothesay mine wound up, but as was common, one region's fall coincided with another region's rise.

Gold discoveries at Nungarra (Aboriginal for 'barb of the spear') brought an influx of miners to the Black Range district. By 1903 about 900 people lived in and around Nungarra, then a proclaimed townsite. Over the next few years the people moved to a settlement about 10 km away due to poor water supplies and no doubt encouraged by a coach route built from Mt Magnet to Lawlers (near Agnew) in the east. One gold-bearing reef at the new settlement had friable and crumbly quartz near the surface, and because of its appearance was known as 'The Sandstone Reef'. This became the township of Sandstone.

The first decade of the 1900s saw many station blocks develop from stock shepherding enterprises to firmly established station businesses with wire fences, windmills, permanent stock yards and homesteads.

Remains of P.M. Morrissey's Weradjaminda station homestead (now part of Bunnawarra) built around 1900

In 1905 a lease was taken up around the Perengary rockhole to the west, to establish a stock trading station for inland bound travellers, prospectors and sandalwood cutters.

Until 1910 the seasons improved, stock numbers increased and it was around this time most leases were amalgamated to become the present stations. Poor seasons then caused a temporary halt to progress and growth in the pastoral industry.

Roaming prospector Thomas Payne registered a mining claim for land at what is now known as Paynes Find in 1911. History suggests that the initial discoverer of gold in this area was actually Timothy Dowd. Mr Payne however, announced his discovery publicly, while Dowd was prospecting elsewhere. The Progress Association of the new settlement acknowledged Mr Dowd's discovery when considering a name for the town. Names such as Dowdsville, Carnation, Auriferous and Coodingnow were considered, but government correspondence had already referred to the area as 'Paynes New Find'. Typically the region saw a large influx of prospectors, some from the Yalgoo fields as mining there had practically ceased. Further to the east, Sandstone continued to expand and by 1912 had a population of about 8,000. Many of the pastoral properties around Sandstone were becoming established. Youanmi had a population of about 300 and to the west there was another gold discovery at the Warriedar Field (Hooper 1986).

From 1917 the pastoral economy improved. Seasons were good, stock numbers continued to rise and the demand for wool was high during World War 1.

Camel team carting wool at Yoweragabbie about 1917 (courtesy of Battye Library WA 9022B)

Apart from a couple of poor seasons in the early 1920s, most of the decade was prosperous for pastoralists. During this time the infant pastoral industry around Sandstone became firmly established. For the mining industry however, the 1920s saw a decrease in activity in the three main centres as profitable alluvial finds were almost exhausted. Sandstone's population fell dramatically and only the pastoral industry helped the towns survive.

The recession of 1929 saw world-wide overproduction of agricultural commodities dumped on the market causing sudden dramatic price drops affecting all sections of the economy (Crowley and de Garis 1969). Rainfall was very low. The combination of events led to very high unemployment, many mining leases becoming vacant, and a plunge in livestock numbers. Cattle numbers never returned to more than 25% of the highest total, not only because demand was low, but because the traditional perception of all pastoral country being good cattle country was not realised.

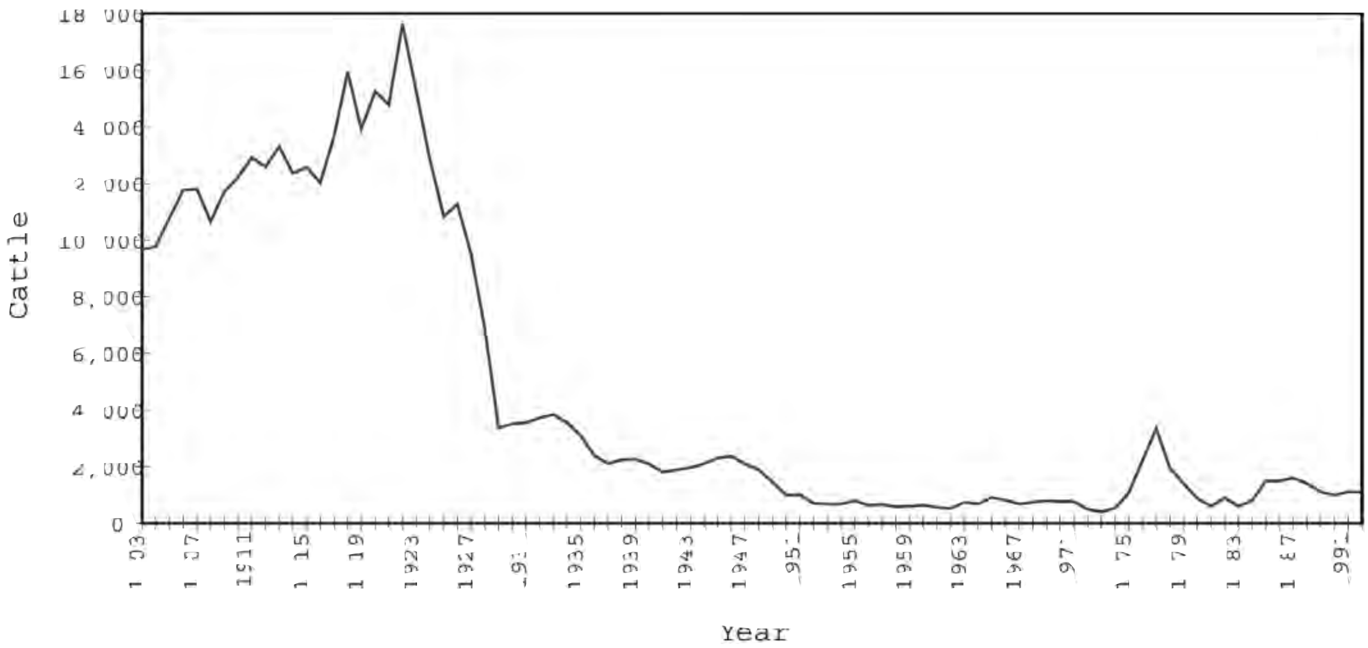

Figure 2. Cattle numbers in the Sandstone-Yalgoo-Paynes Find area, 1903 – 1992

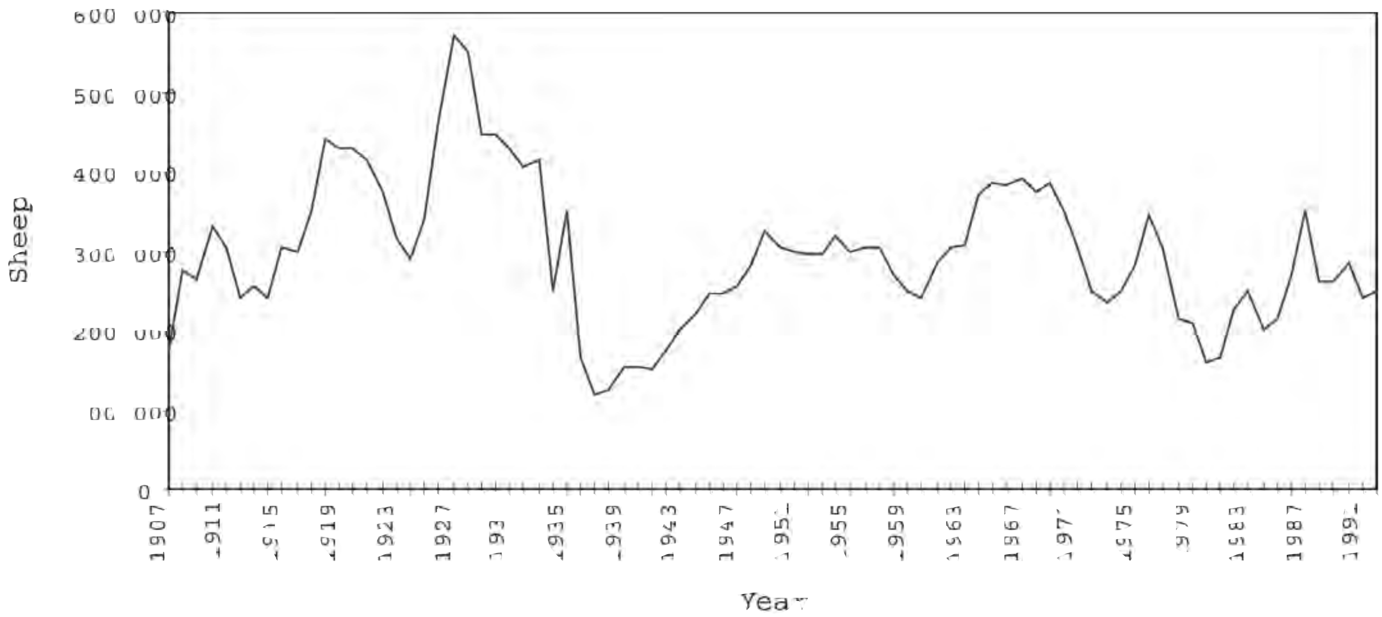

Figure 3. Sheep numbers in the Sandstone-Yalgoo-Paynes Find area, 1907 – 1992

Sandstone's population of 8,000 had fallen to 300 by the early 1930s, yet by the mid-1930s people (unemployed from the Depression) started to return to the mining towns in the hope of starting up old prospects. Individuals such as W.J. (Jack) Green, a Paynes Find resident, did much to help people during the tough times. During the 1920s mining downturn Green saved building materials from abandoned prospects, which became basic shelter for those on the fields during the Depression. Paynes Find's population reached its maximum of 300 at this time.

Prolonged drought from 1936 to 1941 caused severe hardship to pastoral businesses, livestock and land. Fyfe (1940) noted a dramatic decline in the amount of perennial feed available at this time. Perennial plant death was widespread and a matter of great concern to the pastoralists (Burnside 1979). Stock numbers fell beyond expectation (see Figure 2). By 1937 many pastoral workers had to seek alternative work (Hooper 1986) as stations were forced to restructure their financial and labour resources.

World War II brought labour shortages affecting not only mining but the pastoral industry as the 'war effort' was paramount. Wool prices rose again due to the war and during this time the British Government bought the State's entire wool clip (Crowley 1969). Stations however never regained

anywhere near the stock numbers carried prior to the 1930s. That the land could not sustain very high stock numbers had been realised, yet the pastoral industry continued to maintain the local towns as mining industry activity declined in the immediate post-war years.

1950 onwards

Stock numbers generally rose from 1940 before falling sharply in the late 1950s. This fall was offset by the extraordinary high wool prices and demand created by commodity shortages during the Korean War. Wool prices dropped after the war but were still high until the mid-1960s when new synthetic fibres began to compete strongly.

The combined effects of competing synthetics and poor demand caused wool prices to fall again in the early 1970s, wounding the wool industry so much that some properties started taking in cattle (which were realising good prices at the time), in the hope of buffering major future financial fluctuations. The added difficulty of several low rainfall years saw many properties scale down financially, looking to less station employment and the use of more efficient station practices. By way of example, Wilcox (1963) quoted a station labour force of “one man per two thousand sheep” was a “standard ratio” of employment in the early 1960s. Present day station labour is represented by individual families hiring help during busy times such as mustering and shearing. Light aircraft are also used as labour saving devices.

Mining had been relatively quiet, but exploration for minerals other than gold was beginning. A new form of mining also began. The availability of new technology such as hand-held metal detectors, facilitated by the increased popularity of recreational four-wheel-drive vehicles, brought increased activity by both amateur and professional prospectors combing the old alluvial fields, and an increase in tourism.

The late 1970s saw drought conditions for the pastoral industry again which was just recovering from the difficulties experienced a few years prior with poor wool prices. Recessionary times of the late 1980s led to world wool price plunges in 1991, and the removal of Australia’s Wool Reserve Price Scheme made these years the most difficult in memory for pastoralists. As a result, some pastoralists, mostly from smaller properties, now seek off-station employment or have interests in business diversification on the station. There is also an increasing trend for mining companies to purchase the pastoral lease surrounding major mining leases.

The future

With the financial difficulties experienced over the last few decades, some stations have diversified from traditional practice. One key element in keeping people on the land is station lifestyle. Some properties now share this lifestyle with school groups, overseas, interstate and urban dwellers through tourist station stays where guests can learn and participate in every day station life. The popularity of station stays is reflected in the number of stations (seven in the survey area and more than 50 state-wide) catering for tourists.

A stonefruit orchard on Wydgee station is an example of diversification on pastoral land

Horticulture is another emerging form of diversification. A large planting at neighbouring Wiluna and small scale gardens at station homesteads have indicated fruit production has potential with favourable climatic, soil and water conditions. A commercial planting of peaches and nectarines was established recently in the Paynes Find area and an emu farming enterprise on a station south of Paynes Find. Floriculture may also be an option for some properties. Senior (1995) notes that diversification also occurred in the early years. In 1913 a load of antelopes was sent to neighbouring Wiluna and there was a proposal to stock Lake Violet with fish, but success was never realised.

In 1963, Wilcox wrote “...there has been little effort to come to terms with the environment or to conserve its more desirable and enduring features...”. However the emergence of the land conservation ethic over the last 10-15 years sees the pastoral industry endorsing conservative management, with sustainability as a crucial objective. Government and community initiatives are developing strategies for future land use. These goals have led to the formation of Land Conservation Districts (LCDs) through the Landcare scheme. Nature conservation strategies are being considered by some LCD groups and are likely to gain more prominence. Six of these groups (Sandstone, Mt Magnet, Yalgoo, Wiluna, Meekatharra and Murchison) fall wholly or partly within the present survey area. The WA Department of Conservation and Land Management manages Mt Manning and Karroun Hill nature reserves and has acquired the former pastoral stations Mt Elvire and Burnerbinmah.

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Climate

Ken Leighton

The Sandstone-Yalgoo-Paynes Find survey area falls within three bioclimatic regions (Beard 1990) as identified in Figure 1.

Extra-dry Mediterranean – characterised by 7 to 8 months of dry weather, cool wet winters and hot dry summers

Semi-desert Mediterranean – 9 to 11 months of dry weather, mild wet winters and hot dry summers

Desert – often 12 months of dry weather with limited rain occurring both summer and winter.

Bioclimatic regions also tend to delineate natural zones of vegetation. Within the survey area the boundary between the extra-dry and the semi-desert Mediterranean regions coincides with changes of vegetation between the South-West Province and the Eremaean Botanical Province (Beard 1990).

In general it is the availability of moisture, together with the soil characteristics, that determines plant growth. The presence of moisture is a product of the prevailing climate. The survey area often experiences extended dry periods with associated high temperatures – conditions that are not very conducive to plant growth. This all-important relationship between rainfall, temperature and plant growth is explored later in this chapter.

Using a broader classification (Bolton 1983), approximately half of the area falls within an arid climate. The distinction between arid and semi-arid climatic zones roughly coincides with the 250 mm isohyet (Figure 2).

In these arid zones the 'socio-climate' is expressed as the combined effects of the meteorological variables of temperature, humidity, wind, solar radiation, and the human variables of metabolic heat rate and clothing insulation (Colls and Whitaker 1995). The quantification of the socio-climate of an area (relative strain index) provides a relative indication of the attraction of the physical environment for settlement. The number of discomfort days per year in the survey area ranges from 50 to 100 (south-west to north-east), while by comparison in the Kimberley the number exceeds 200 and Perth has 10 to 25. Obviously the presence of more compelling reasons for settlement, other than socio-climate, will ultimately determine habitation choice.

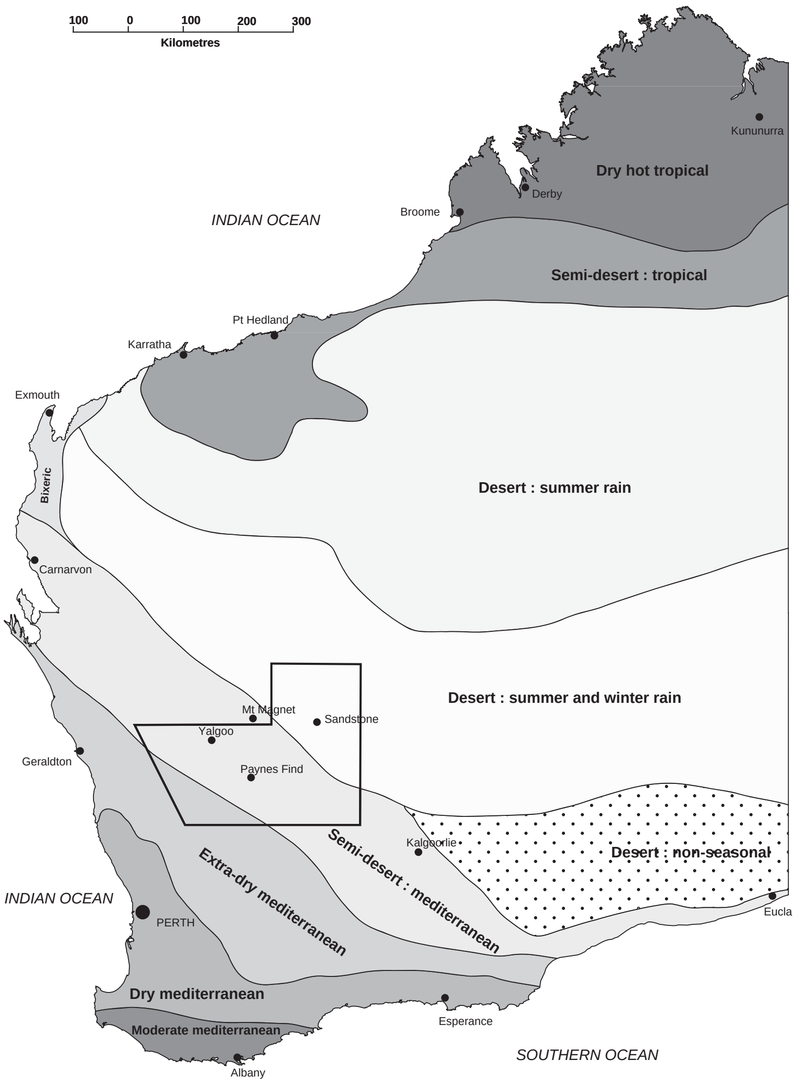


Figure 1. Bioclimes of Western Australia (after Beard 1990)

Sources of climate data

The Bureau of Meteorology supplied climate records for the sites listed in Table 1. This is not an exhaustive list of all past and current recording stations within the survey area, but was chosen to provide representative coverage for the purposes of data analysis. The table includes the geographical location and some of the climatic extremes for each centre. Unfortunately, in 1975 the re-prioritising of government funding prompted the recording stations at Booylgoo Spring, Mt Magnet and Yalgoo to cease some or all of their operations; Booylgoo Spring discontinued recording rainfall (uninterrupted since 1922) in 1993; Yalgoo continues to record rainfall (after a short break in the 1970s); Mt Magnet started recording again in 1985 after a 10 year interruption, and is now serviced by an automatic weather station (AWS).

It is regrettable that continuity of recording was broken at these long established stations, as the later period, particularly since 1968, has figured strongly in research into contemporary climate change in Australia (Steering Committee on Climate Change 1995).

Figure 3 identifies the recording stations in and adjacent to the survey area and summarises their data recording histories. Only six of the available datasets were used to graphically present climate analysis in this report, however, the others helped complete a more comprehensive scenario.

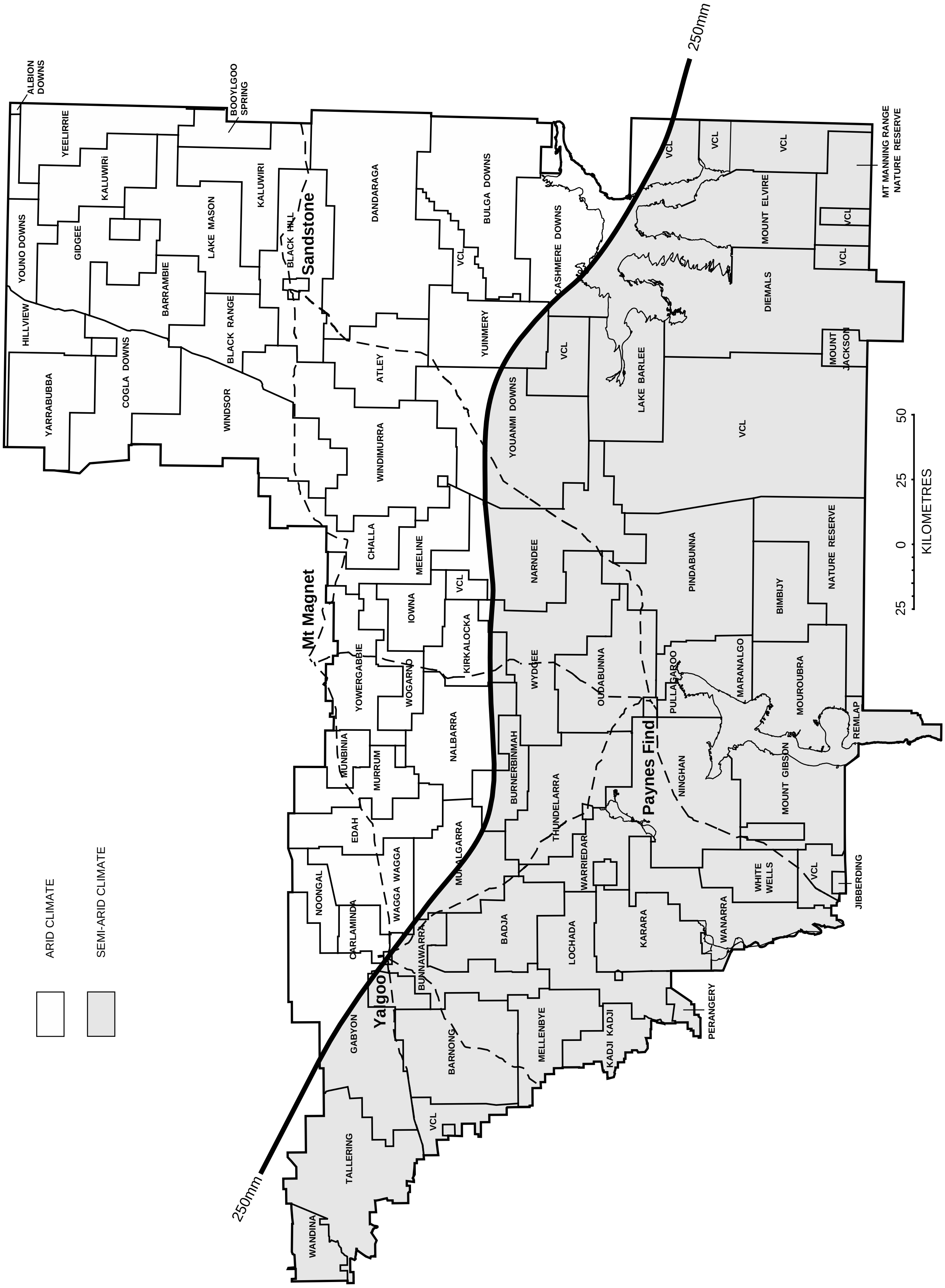


Figure 2. Position of 250 mm (mean) isohyet dividing the survey area into semi-arid and arid climatic zones

Table 1. Climatic data recording centres, their position, history and some climatic extremes

Recording centre	Latitude (S)	Longitude (E)	Elevation (m)	Years of temperature observations	Lowest recorded daily min. temp. (°C)		Highest recorded daily max. temp. (°C)		Years of rainfall observations	Lowest recorded annual rainfall (mm)	Highest recorded annual rainfall (mm)	Median rainfall (mm)
					January	July	January	July				
Booygloo Spring	27° 45'	119° 54'	610	11	13.9	-6.7**	43.6	27.9	71	64 (1935)	608 (1975)	188
Cashmere Downs	28° 28'	119° 34'	500	22	10.6	-4.2	45.5	26.6	66	78 (1936)	616 (1975)	219
Diemals	29° 40'	119° 18'	434	17	11.0	-3.6	46.5	26.6	24	146 (1977)	542 (1992)	237
Mt Magnet*	28° 04'	117° 51'	426	27	11.4	-1.5	46.1	28.7	100	73 (1911)	590 (1992)	220
Paynes Find	29° 16'	117° 41'	339	14	9.3	-3.4	46.5	25.7	36	99 (1969)	539 (1992)	273
Yalgoo	28° 21'	116° 41'	318	40	9.4	-2.5	46.1	28.9	95	52 (1976)	524 (1992)	233
Barnong	28° 38'	116° 17'	350						94	98 (1940)	526 (1927)	265
Challa	28° 17'	118° 19'	425						100	54 (1959)	570 (1992)	180
Cogla Downs	27° 26'	118° 56'	500						56	69 (1969)	546 (1942)	191
Mouroubra	29° 48'	117° 42'	350						50	139 (1969)	521 (1992)	276
Murrum	28° 16'	117° 23'	350						50	66 (1976)	459 (1992)	200
Narndee	28° 57'	118° 11'	450						74	95 (1924)	587 (1973)	258
Sandstone	27° 59'	119° 18'	550						91	72 (1976)	699 (1975)	216
Thundelarra	28° 54'	117° 08'	300						90	104 (1911)	569 (1918)	215
Yuinmery	28° 34'	119° 01'	450						74	53 (1944)	646 (1975)	213
Badga	28° 36'	116° 47'	320						16			*260*
Muralgarra	28° 32'	117° 02'	350						87			*238*
Nalbarra	28° 39'	117° 36'	350						87			*241*
Wagga Wagga	28° 20'	116° 56'	350						19			*261*
Wydgee	28° 51'	117° 50'	400						88			*269*
Youanmi Downs	28° 33'	118° 49'	500						72			*249*

*recording station outside survey area ** lowest temperature ever recorded in WA

Figures in italic are mean values

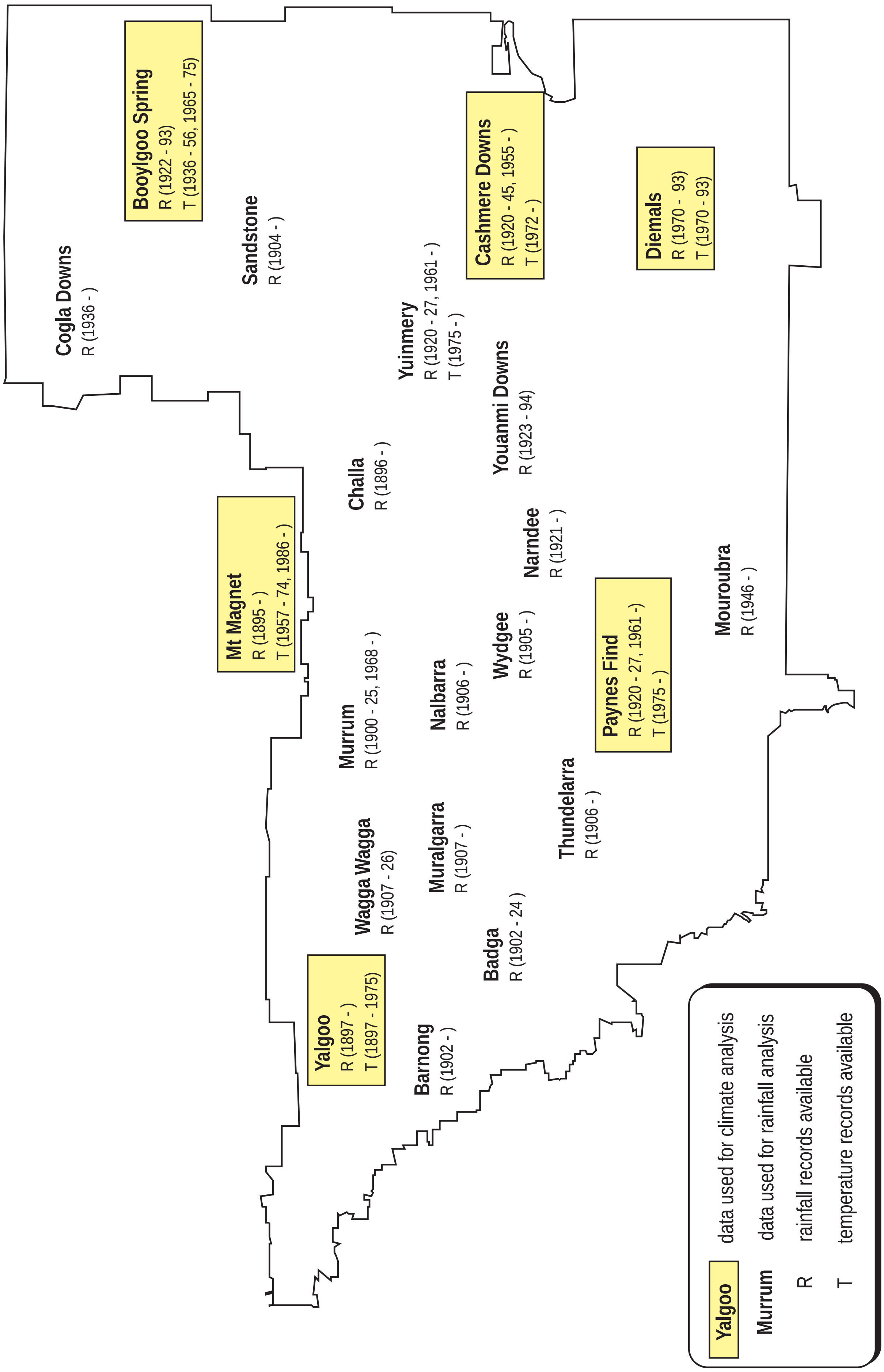


Figure 3. Recording centres and their history of data collection

Major climatic patterns

Summer patterns (November to April)

Throughout the year Australia's weather is influenced by the passage of anticyclone systems, commonly referred to as high pressure systems. These travel across the continent from west to east in summer at a mean latitude of 37°S (which passes close to Melbourne). The anticyclones have an anticlockwise circulation which produces easterly winds to the north and westerlies to the south. Irregular incursions of moist air from the north, often associated with the remnants of tropical cyclones, produce infrequent rain within the survey area. With the prevailing winds ranging east-south-easterly, the air has a lengthy passage overland and therefore produces little rain The presence of summer low pressure systems over the interior, commonly referred to as heat lows, produces intense hot, dry conditions.

In all locations within the survey area the summer weather pattern is characterised by high daily temperatures with little relief at night, and easterly winds easing and turning to south-easterly at night. Rainfall is only summer dominant in the north-eastern half. Local flooding is uncommon.

Winter patterns (May to October)

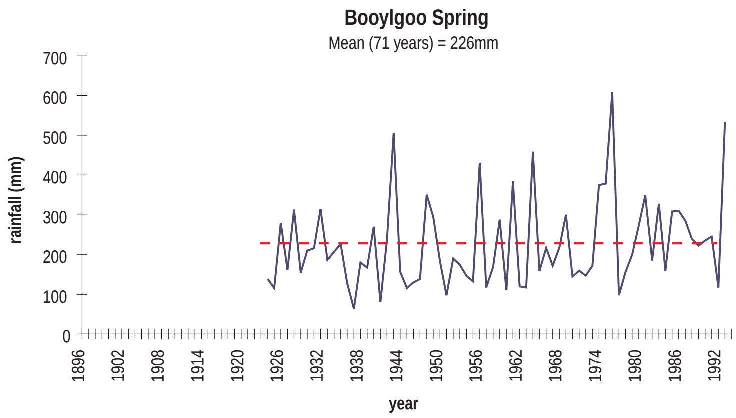
In winter and spring the west-east passage of the anticyclone systems moves northward with the thermal equator, to a mean latitude of 29°S (in line with Brisbane). These anticyclones often remain stationary over the continent for several days and during this time the prevailing cool, moist westerly winds and associated cold fronts produce rain periods. Wind direction tends to be from the western quadrant in the morning, generally increasing in speed and prevailing from the north-west in the afternoon.

Daily winter temperatures are generally cool and may fall to below freezing point at night, particularly when the anticyclones are centred over the survey area. Rainfall in the south-eastern half is winter dominant although throughout the area September and October are the driest months. Local flooding or sheetwash can occur and the large salt lakes may fill (as in 1992).

Climatic factors

Rainfall

In Australia a 'normal' rainfall year seldom exists. As identified in Figure 4 the average rainfall is created by more years being below the average (57% Yalgoo, 64% Booylgoo Spring) but with some very wet years helping to balance. Median rainfall is often quoted as giving a better indication of yearly rainfall (Figure 5). Rainfall is both irregular and highly variable across the survey area (Castles 1994). In simple terms the rainfall variability ranges from moderate to very high – the categories being computed from annual (90, 50 and 10%) rainfall percentiles (State of the Environment Advisory Council (Australia) 1996). It is this characteristic which renders areas of otherwise compatible soils unsuitable for agricultural cropping. The local rainfall patterns are also extremely variable, with pastoral stations recording significantly different amounts of rain across the property. Widespread major falls are rare, more common are local falls either from frontal activity in winter or thunderstorms in summer. Local hail can cause severe damage to vegetation.



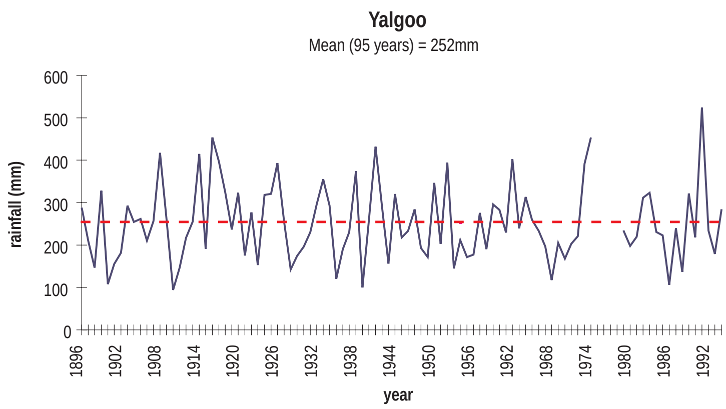


Figure 4. Annual rainfall history for two centres

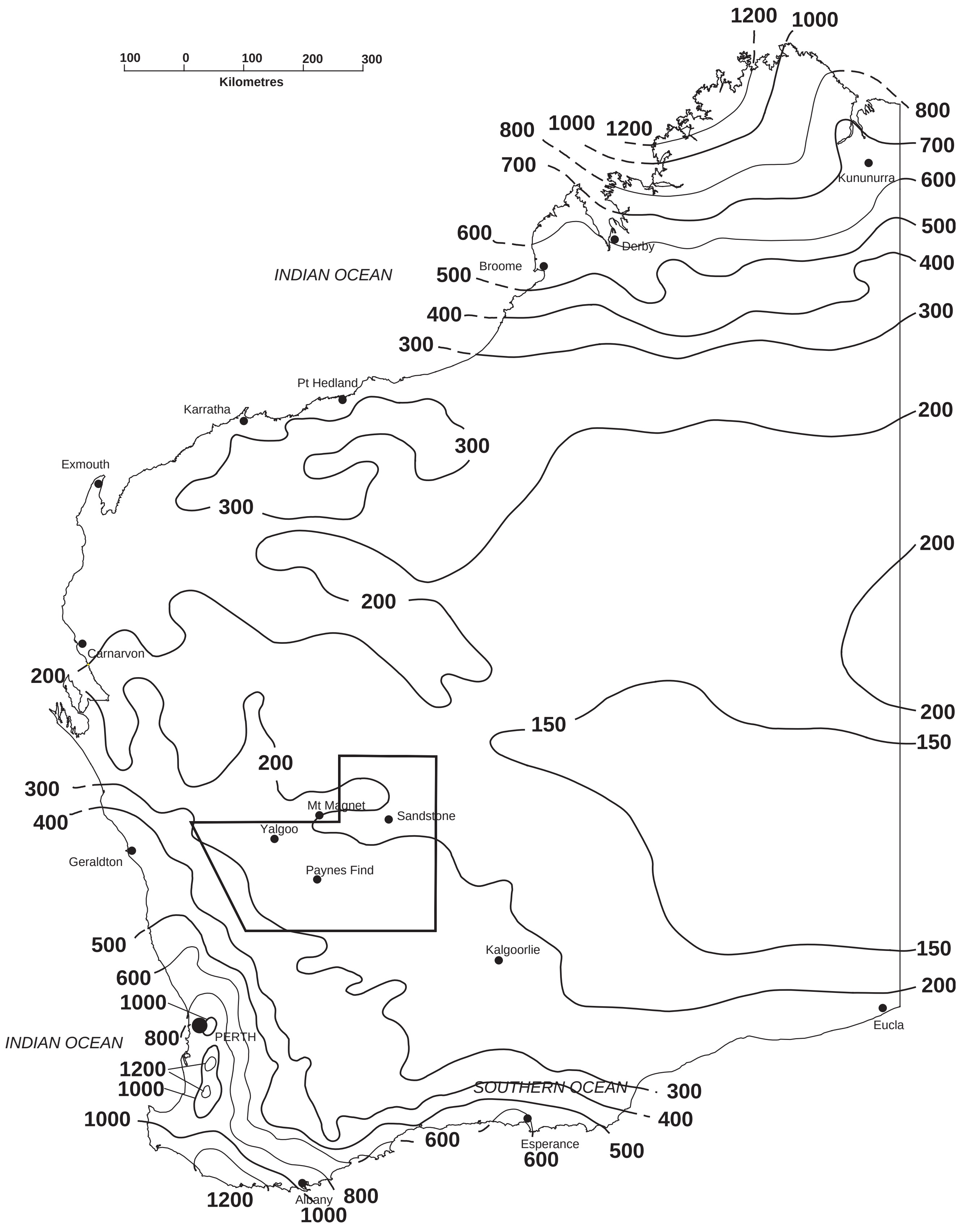


Figure 5. Median annual rainfall in Western Australia (Bureau of Meteorology 1988)

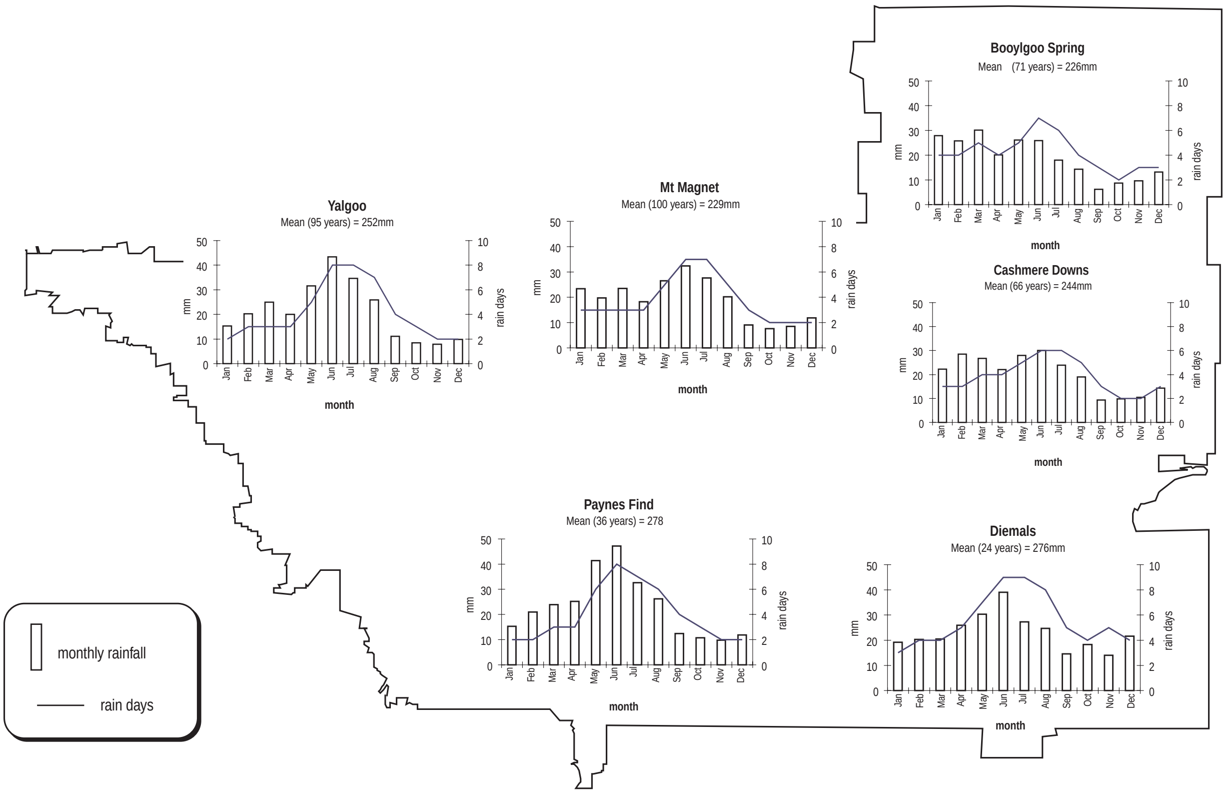


Figure 6. Mean monthly and annual rainfall and number of rain days

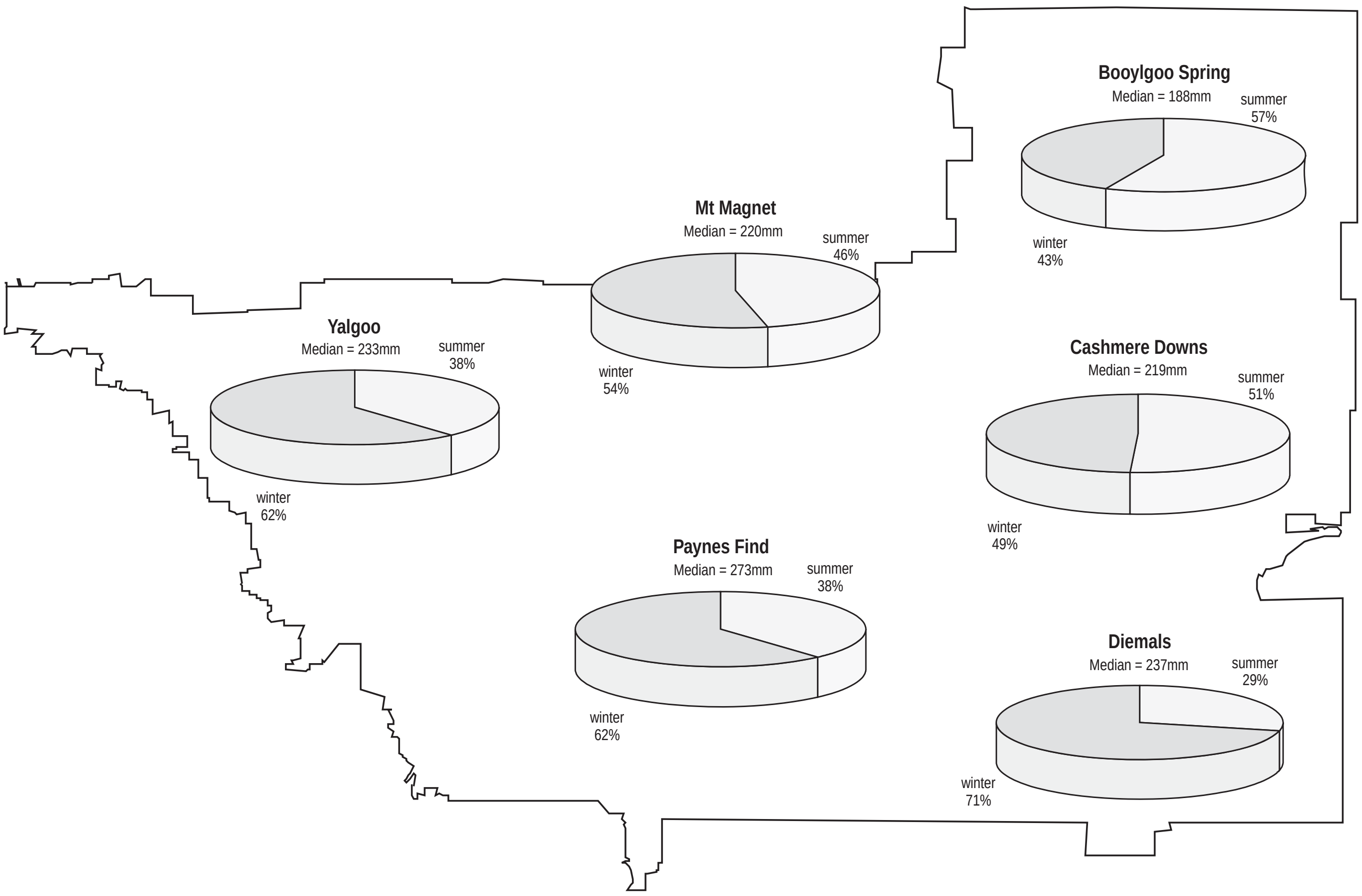


Figure 7. Proportions of average winter and summer rainfall

Figure 6 presents rainfall data for six recording stations within and adjacent to the survey area. Rainfall ranges from winter-dominant in the south and west (about two-thirds of the survey area), to summer-dominant in the north-east (Figure 7) with a corresponding decrease in yearly median values from 273 mm at Mouroubra to 180 mm at Challa. This is significant because it helps explain why the entire survey area has a more pronounced winter growing period even though there is a distinct summer/winter rainfall demarcation.

Table 2. The annual number of rain days (rainfall greater than 0.2 mm) at Booylgoo Spring and Yalgoo

	Booylgoo Spring	Yalgoo
Yearly average	48	50
Lowest recorded	23 (1944)	27 (1944)
Highest recorded	89 (1963)	103 (1915)
Winter (Jun-Aug) average	17	23
Summer (Dec-Feb) average	11	7

Drought

The term 'drought' is widely used to describe periods of water (rainfall) shortage. These can be short or long-term periods (which quantify 'severity'); are commonly seen to be recurrent in nature; can be widespread or localised and more recently have been recognised as being caused by the variations in the El Nino Southern Oscillation (ENSO) phenomenon. The Bureau of Meteorology considers that a drought event has occurred if the annual rainfall is within the first decile range (lowest 10%) of the average for that centre.

The drought risk map (Figure 8) categorises the susceptibility of the survey area to drought. The categories are determined from index values based on percentile measures of the variation of annual rainfall (Colls and Whittaker 1995).

Most extended periods of below average rainfall within the survey area were recorded around 1928, 1936, 1953, 1968, 1986 at Yalgoo and 1924, 1936, 1944, 1952, 1969, 1976, at Booylgoo Spring. Figure 4 plots the history of annual rainfall for Booylgoo Spring and Yalgoo.

The severity of a drought will also be influenced by the amount of surface evaporation and soil moisture. Low rainfall on its own does not necessarily constitute a drought if that rainfall comes at opportune times for peak growth periods. (See later for discussion on effective rainfall.)

Studies quoted in Reynolds *et al.* (1983) indicate that in WA, 54 years in 100 will experience drought conditions, i.e. any continuous three-month period will lie below the 10 percentile rainfall value. Given that within the survey area from west to east the percentage of years with below average rainfall ranges from 50 to 69% it demonstrates that 'drought' mitigation measures of pastoral management should be normal practice. The only effective counter to lessen the effect of extended periods of low rainfall is to adopt management strategies which minimise losses when the problem arises (Reynolds *et al.* 1983).

Temperature

Figure 9 shows almost identical temperature profile trends for day and night across the survey area. Comparison of mean daily temperatures (Table 3) for Booylgoo Spring, Diemals, Mt Magnet and Yalgoo reveals minor regional differences. (Winter includes only the months June-August, and summer includes only December-February.)

Table 3. Mean winter and summer temperatures at four centres

	Booylgoo Spring	Diemals	Mt Magnet	Yalgoo
Mean winter day-time (°C)	18.5	19.5	19.5	19.1
Mean winter night-time (°C)	5.2	4.6	7.4	6.9
Mean summer day-time (°C)	35.3	35.3	39.0	36.3
Mean summer night-time (°C)	18.5	18.2	21.3	19.9

The extremes of temperature experienced at recording stations within and adjacent to the survey area are summarised in detail in Table 1.

Figure 9 shows that diurnal temperature fluctuations are approximately consistent during the year, i.e. approximately 13°C in July and 16°C in January. Such fluctuations are a result of high global radiation conditions which generally prevail with low humidity and normally little cloud to restrict incident or reflected radiation (Arnold 1963).

Some frosts do occur, more commonly to the east, however they are rarely severe enough to affect native vegetation (Gilligan 1994). A group of two or three frost days might occur when an anticyclone follows a southern depression bringing a strong flow of cold air (Arnold 1963).

Summer heatwave conditions are an annual occurrence across most of arid Australia. These are caused by the development of a low pressure system (or heat low) in association with a trough to the west of a slowly passing anticyclone. Daytime temperatures to the east of the trough will then rise appreciably and will remain high while conditions remain stable. Usually, after a few days the systems will continue eastwards followed by cooler north-west to south-west winds which will bring a cool change to the region. The cycle continues as a new anticyclone moves into the area (Curry *et al.* 1994). Using the temperature records of Wiluna (a town just outside the survey area to the north-east with 87 years of records) and Yalgoo, Figure 10 shows the five-year moving average for the annual number of days in excess of 30 and 40°C. While the number of days exceeding 30°C appears relatively stable there is a marked increasing trend in the annual number of days exceeding 40°C. In Wiluna from 1907-52 the average number of days per year over 40°C was 20, whereas from 1952 onwards it is 29. For Yalgoo the numbers are 16 and 24 days respectively.

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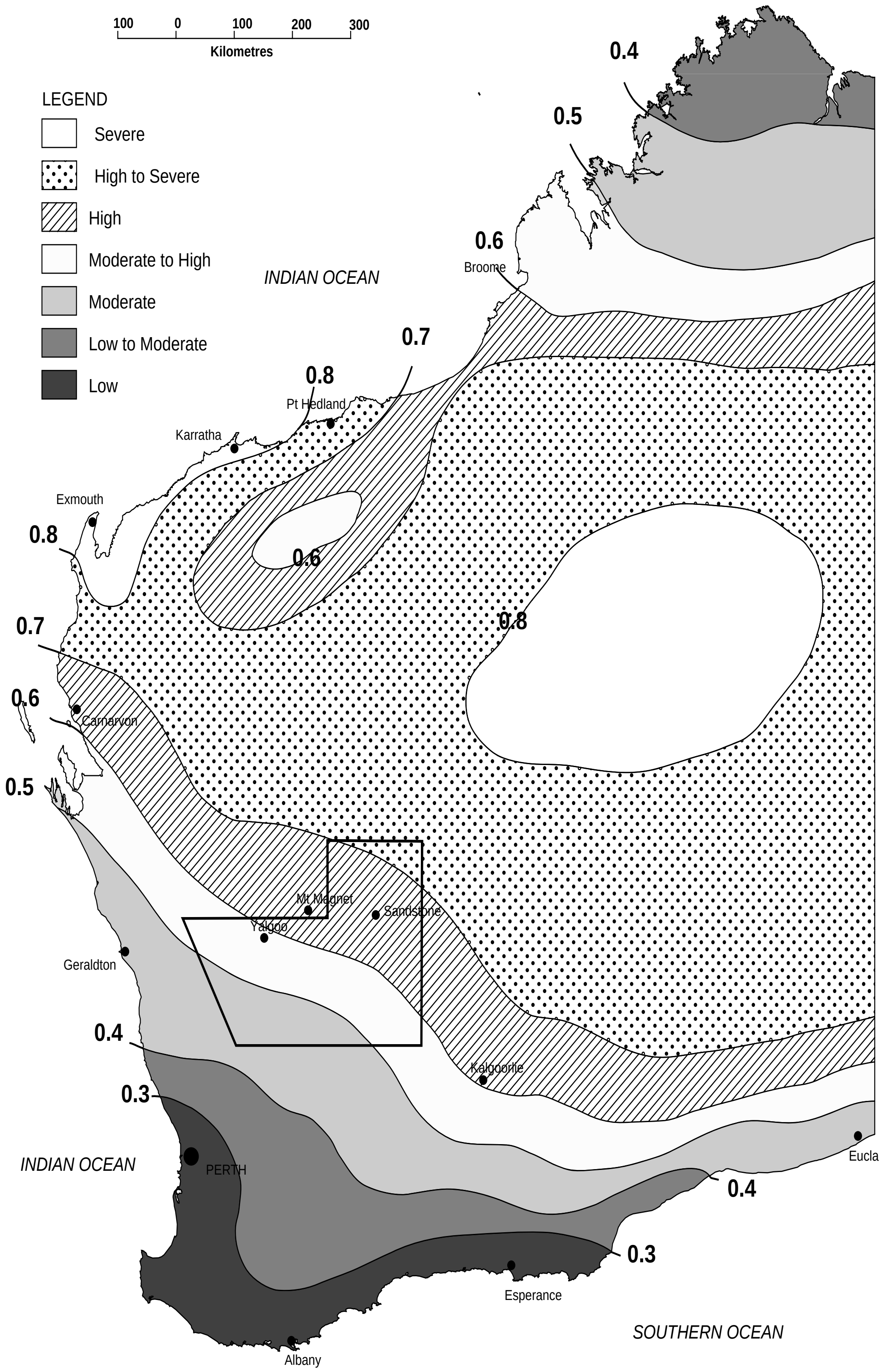


Figure 8. Drought risk index in Western Australia (Colls and Whitaker 1995)

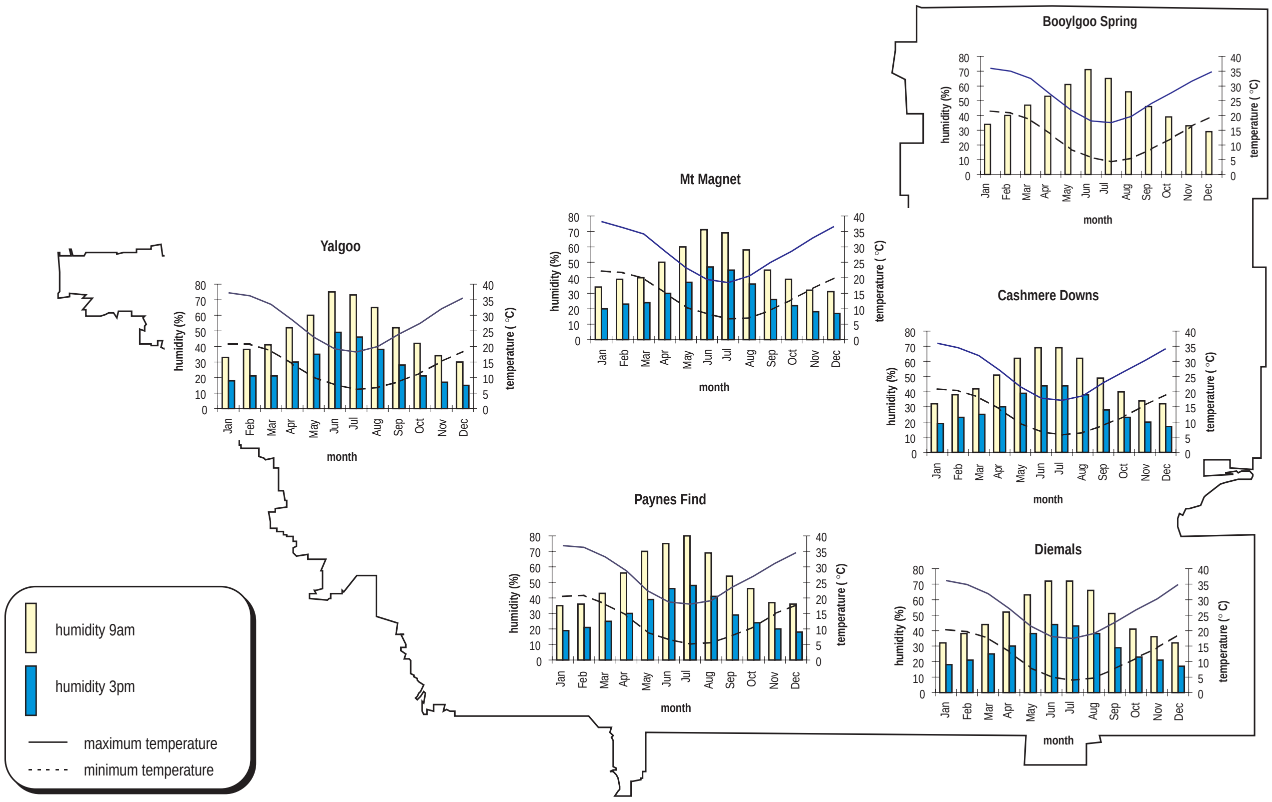


Figure 9. Mean monthly humidity and day/night temperatures

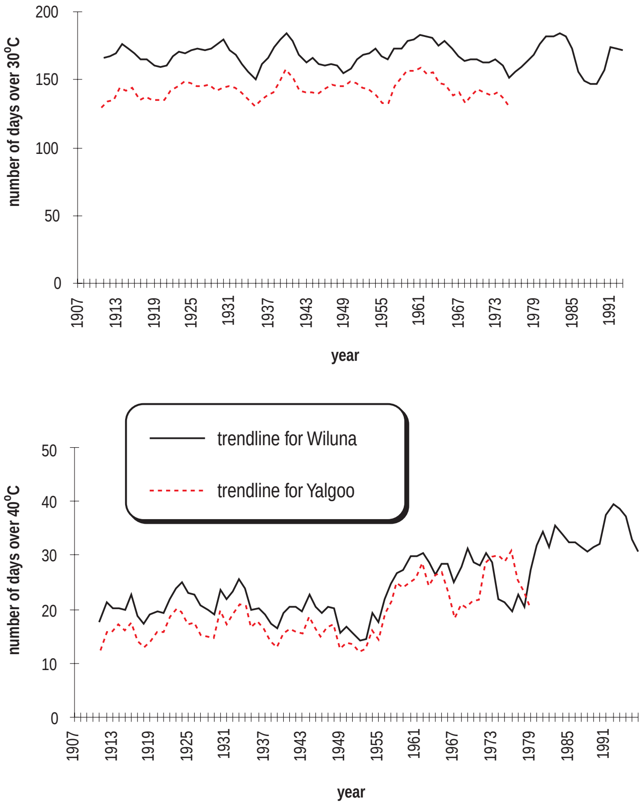


Figure 10. Five year moving average of the annual number of days in excess of 30°C and 40°C

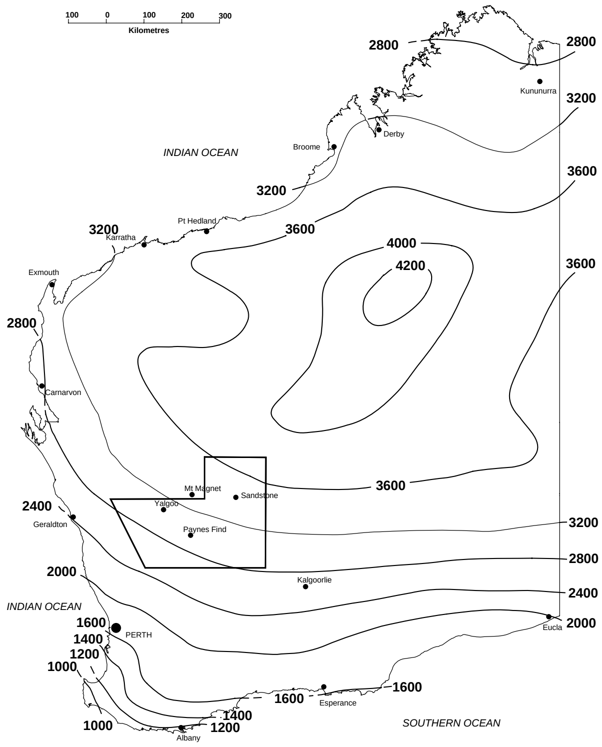


Figure 11. Average annual evaporation (mm) in Western Australia (Bureau of Meteorology 1988)

Humidity

Mean relative humidity within the survey area for 9 am ranges from 34% in summer to 69% in winter. At 3pm the range is from 19% in summer to 43% in winter. Relative humidity will also tend to be higher if winds have originated in the west rather having blown extensively over the land from the east.

Being inversely proportional to temperature, relative humidity will always be greater when the temperature is at the minimum around dawn, and least when temperatures are high in the afternoon. Figure 9 shows very little significant difference between recording centres.

Dew

Within the survey area the dew point in the summer months of December to February is 10°C, whilst for the mid-winter months the average is 5°C. In summer the mean minimum temperature is about 20°C, or 10°C above the dew point so dew would not normally be expected except during rainy periods. In winter the mean minimum temperature is 6°C, only 1°C above the average dew point. The likelihood of dews is therefore very high especially in the east where mean minimum temperatures for June, July and August are consistently below the dew point.

Frosts, which occur more commonly in the east of the survey area minimise the effect of dew-fall. The significance of dew to plant growth is greater if mild, frost-free mornings are accompanied by consistent dew-fall.

Evaporation

Evaporation is the single most important contributing factor to water loss in arid Australia. It therefore has considerable influence on water conservation both in terms of plant and animal systems.

As for most of Australia average annual evaporation in the survey area is considerably higher than rainfall. Evaporation values (Figure 11) ranging from 2,500 to 3,600 mm exceed the rainfall range (Figure 5) of 200 to 300 mm by a factor of 12.

Evaporation data is now only collected at Paynes Find (yearly average 2,480 mm). Limited historical data is available from Mt Magnet and Yalgoo recording stations. Meekatharra, Cue and now Mt Magnet AWS, all adjacent to the survey area, collect evaporation data.

Prevailing winds

Winds are generally a result of the dominant synoptic systems. They are noticeably less variable than those on coastal areas which are influenced by ‘sea breezes’, however this sea breeze influence does extend to the very west of the survey area. The prevailing wind diagrams in Figure 12 show how the average speed and directions change both daily and seasonally across the survey area. Wind direction within the survey area tends to be predominantly from the south to south-east quadrant. Winds from the opposite quadrant usually indicate an imminent weather change.

There are times during the year when the easterly passage of a high is blocked with subsequent prolonged absence of wind, sometimes lasting up to two weeks. This creates wind

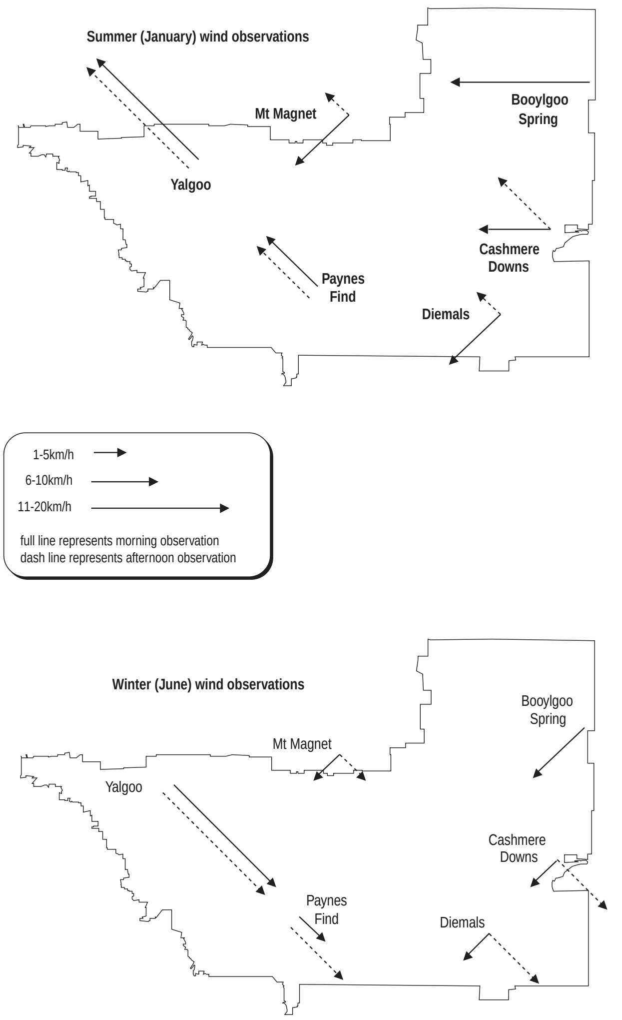


Figure 12. Summer and winter prevailing wind speed and direction – morning and afternoon

droughts which particularly in summer can have serious implications where stock rely on water being pumped by windmills and where limited tank reserves and stock pressure exacerbate the problem.

The ubiquitous high pressure systems, or anticyclones, are a feature of Australia’s position within the mid-latitudes. These move slowly eastward and produce the two main wind streams being easterlies to the north and westerlies to the south. The latitude of the axis of each anticyclone is the determinant of the prevailing wind. Winds within the survey area predominantly originate from the south-east which tends to rationalise the common observation that sheep graze into the wind resulting in more intense grazing pressure in the south-east quadrant of a paddock, especially if a watering point is present.

Rainfall effectiveness and estimated periods of plant growth

The availability of soil moisture is the most dominant factor influencing plant growth in arid and semi-arid regions. Rainfall, from which most soil moisture is derived, is most effective for plant growth if it comes as a combination or series of episodic falls. This is far preferable than receiving the average or total annual rainfall as one or a few major

events which are likely to cause more damage than good. Therefore it is more appropriate to identify and describe the nature of annual rainfall which provides favourable conditions to induce plant growth. Growing conditions are also influenced by temperature which, if very low as in some winters, tends to retard growth and in summer increases the rate of evaporation loss from soil and vegetation.

This relationship between temperature and rainfall can be demonstrated using long-term records from selected centres in the survey area. Ombrothermic charts (Beard 1990) show the annual average length of the growing season (see Figure 13). Periods where the rainfall line falls below the temperature line are considered ‘dry’. During those months precipitation is generally inadequate to sustain plant growth, however, plant adaptation to the local environment means that growth can be maintained albeit at a much reduced rate. The charts show a consistency between centres respectively located within the semi-arid and arid climatic zones.

A more rigorous assessment of rainfall effectiveness is provided by the WATBAL computer model which measures rainfall effectiveness in terms of availability of sufficient soil moisture to promote vegetation growth. Dr Ian Foster (Agriculture Western Australia) has analysed data for the six recording centres in the survey area to produce the annual number of pentads (five-day periods) of likely vegetation growth. The criteria adopted for effective winter rains (May-October) is six pentads (30 days) of continuously favourable soil moisture and four pentads (20 days) for effective summer rain (November-April), after an initial rain event of 15 mm. The program takes rainfall and potential evapotranspiration for each pentad into account. It also takes into account water loss from internal drainage and run-off, and compares the incoming rainfall against a proportion of the potential evaporation presumed to be for plant growth or germination. If there is a store of water remaining in the soil at the conclusion of the pentad, then plant growth is considered to have occurred.

Table 4 lists the average start date for each of the six centres and the average length of the growing seasons. It also shows the duration of the best and worst seasons on record. Regionally the predominant growing season is winter even in those areas with greater rainfall occurrences in summer, i.e. to the north-east of the survey area. Paynes Find in the south-west has the longest winter and yearly growing season total (116 and 134 days respectively) with Booylgoo Spring having the shortest winter (78 days).

The lengths of the annual longest continuous growth period for both winter and summer growing seasons for each of the six centres are shown in Figures 14a,b,c. These are graphed against the criteria for effective rainfall of 30 days in winter and 20 days in summer. As in Figure 4 there is no evidence of any significant recurrent patterns during the century, nor of regular cycles of seasonal length. However, it is readily apparent that some centres enjoy much more reliable favourable seasons than others. Table 5 summarises the number of effective and failed seasons for both winter and summer for each of the centres. Yalgoo, for example, is fortunate to have 97% of all years on record producing an effective winter season, whereas Booylgoo Spring has only 79% effective winter seasons. The exact opposite occurs in summer with Yalgoo recording only 13% effective seasons while Booylgoo Spring enjoys 34%.

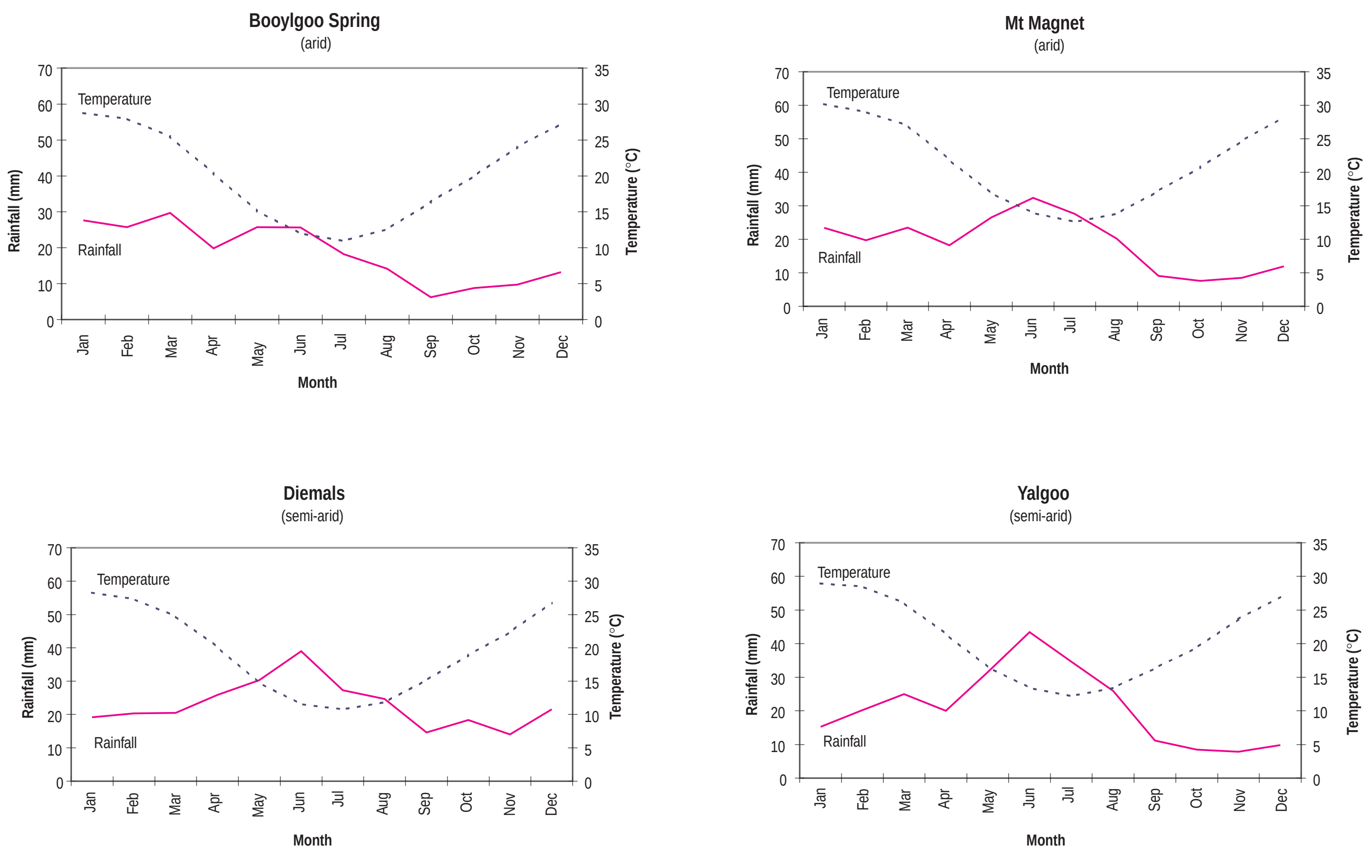


Figure 13. Ombrothermic diagrams for four centres (months with rainfall line under tempertature line are considered dry)

Table 4. Average start date of effective winter and summer seasons, their average length and extremes

	Booylgoo Spring	Cashmere Downs	Diemals	Mt Magnet	Paynes Find	Yalgoo
Average starting date for an effective winter	9 May ± 47 days	15 Mays ± 35 days	20 May ± 17 days	29 May ± 20 days	20 May ± 19 days	24 May ± 17 days
Average starting date for an effective summer	3 Mar ± 35 days	1 Mar ± 39 days	14 Feb ± 65 days	25 Feb ± 31 days	15 Mar ± 50 days	5 Mar ± 34 days
Average length of winter growing season (days)	78 ± 39	92 ± 37	108 ± 32	80 ± 32	116 ± 29	100 ± 25
Average length of summer growing season (days)	24 ± 18	21 ± 17	23 ± 17	19 ± 19	18 ± 17	14 ± 14
Best winter season (days)	185	185	185	185	185	175
Worst winter season (days)	0	5	15	5	20	20
Best summer season (days)	70	65	50	25	65	35
Worst summer season (days)	0	0	5	0	0	0

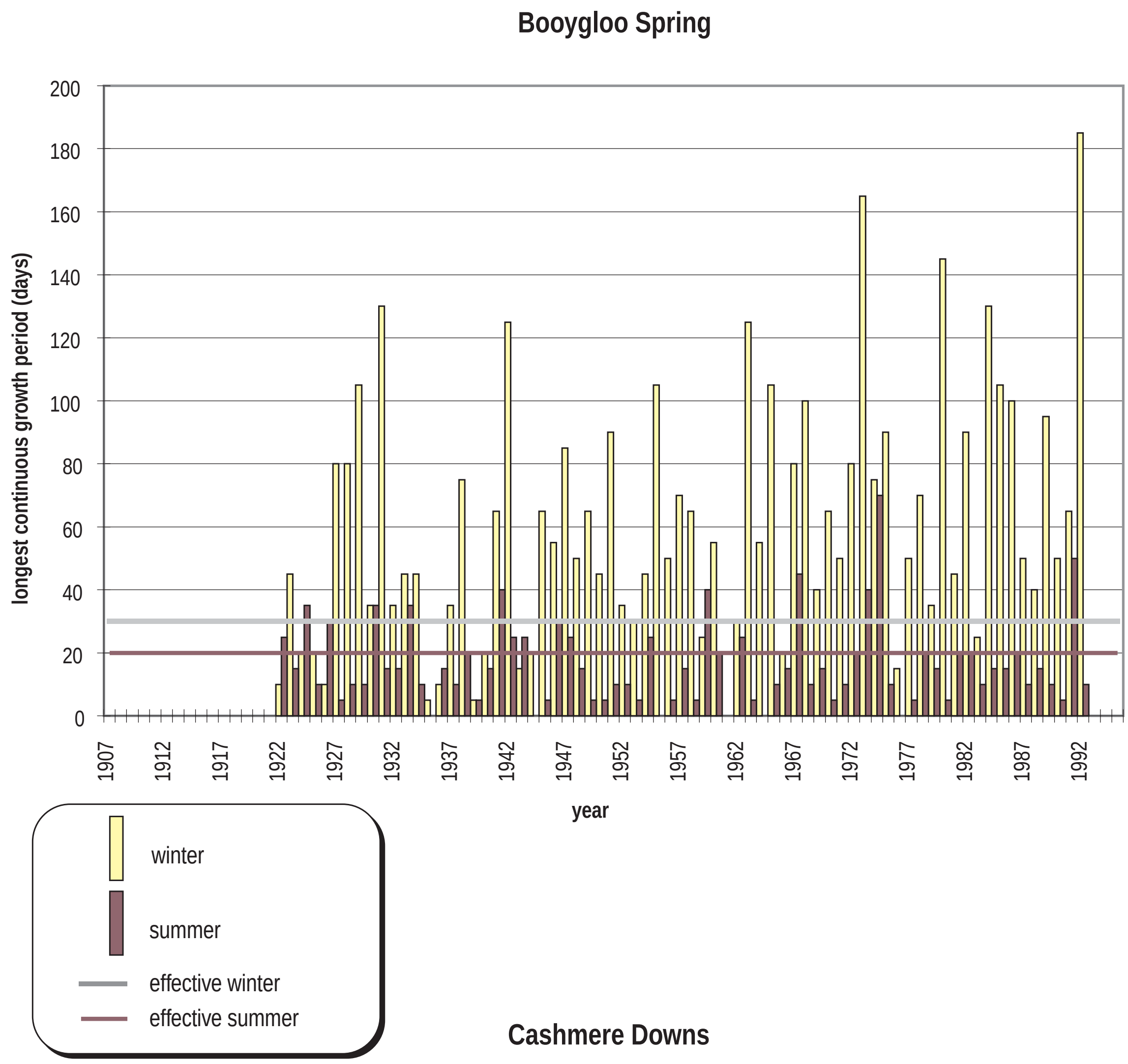
Table 5. The number of effective and failed seasons for winter and summer

	Booylgoo Spring	Cashmere Downs	Diemals	Mt Magnet	Paynes Find	Yalgoo
Number of effective winter seasons(>30 growing days)	57 (79%)	63 (81%)	23 (96%)	76 (84%)	84 (93%)	87 (97%)
Number of failed winter seasons(<30 growing days)	15 (21%)	15 (19%)	1 (4%)	14 (16%)	6 (7%)	3 (3%)
Number of effective summer seasons(>20 growing days)	24 (34%)	25 (32%)	6 (26%)	19 (21%)	21 (24%)	12 (13%)
Number of failed summer seasons(<20 growing days)	47 (66%)	52 (68%)	17 (74%)	70 (79%)	68 (76%)	77 (87%)

Periods of minimum availability of soil moisture were common across the survey area. The periods 1922-23, 1935-37, 1952, 1976-77 and 1983 in particular would not have provided much support for plant growth and whilst dry periods for 6 to 12 months are quite common, extended ‘droughts’ are not. The Pastoral Board, for the purposes of assessing drought relief, have in the past, defined drought as having occurred if successive winter, summer, winter, summer seasons failed, i.e. they produced less than the required 30 and 20 day respective growth periods. Using this definition, Figure 14 shows that Cashmere Downs recorded four droughts in 73 years of records, Mt Magnet has recorded three droughts in 88 years, and Paynes Find and Booylgoo Spring recorded two droughts in 88 and 71 years respectively. (The difference between the number of years of records at some centres when compared with figures in Table 1 has come about because of amalgamations with defunct adjacent centres. Similarly some years had been excluded from the WATBAL analysis where the records have been deemed unreliable.)

Long-term seasonal expectations of soil moisture can be expressed in terms of probabilities from which it is possible to predict the number of days of continuous growth. For example Figure 15 shows that for Yalgoo there is a 60% chance that the winter growth period will exceed 80 days, whereas there is only a 10% chance that the summer growth period will exceed 20 days. (Note that the graph line for Yalgoo and Mt Magnet is coincident.) Remembering that for an effective winter season 30 days of continuous growth are required, then there is an 80% probability that Mt Magnet and Booylgoo Spring will enjoy an effective winter and better than 90% probability that both Yalgoo and Diemals will also succeed. For summer Yalgoo and Mt Magnet share a 10% probability that they will receive 20 days of continuous growth, whereas there is a 20% and 30% probability that Diemals and Booylgoo Spring will receive effective summers.

The pastoral management implications which climate imposes are discussed in the companion publication entitled ‘Pastoral resources and their management in the Sandstone-Yalgoo-Paynes Find area, Western Australia’ (Van Vreeswyk and Godden 1998).



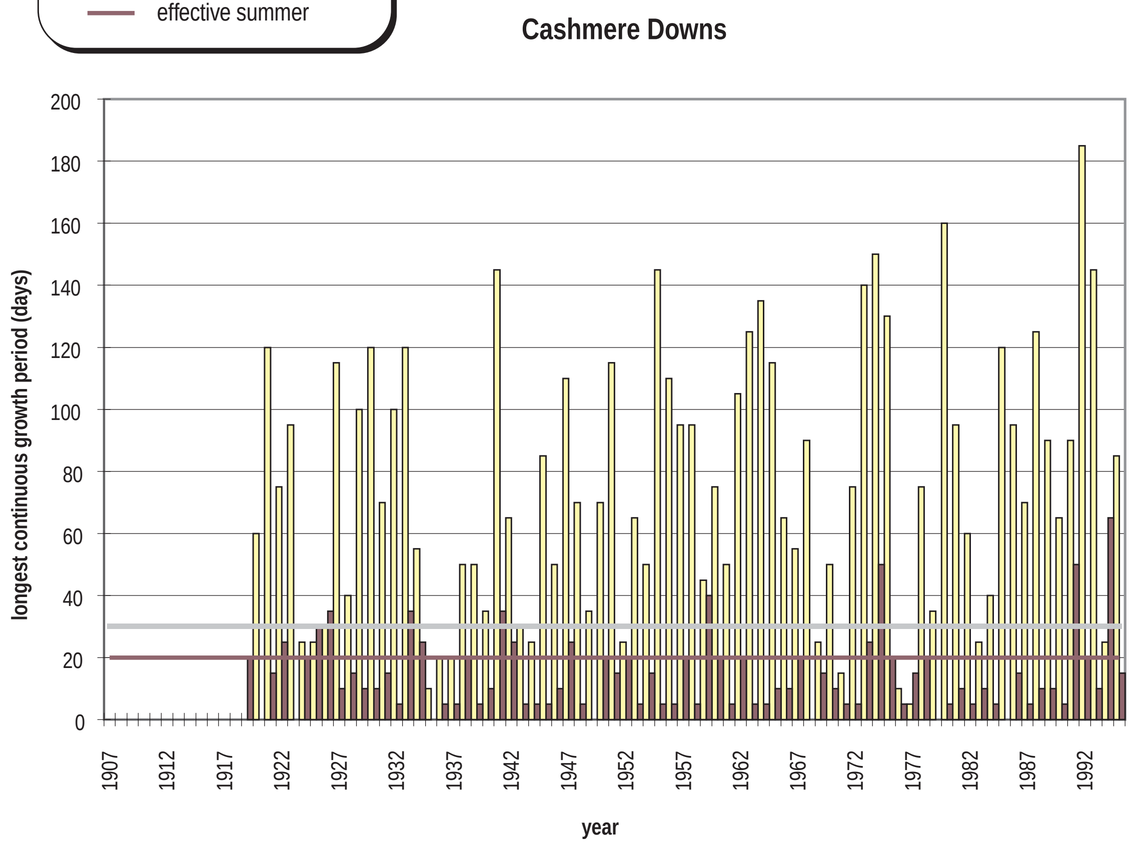
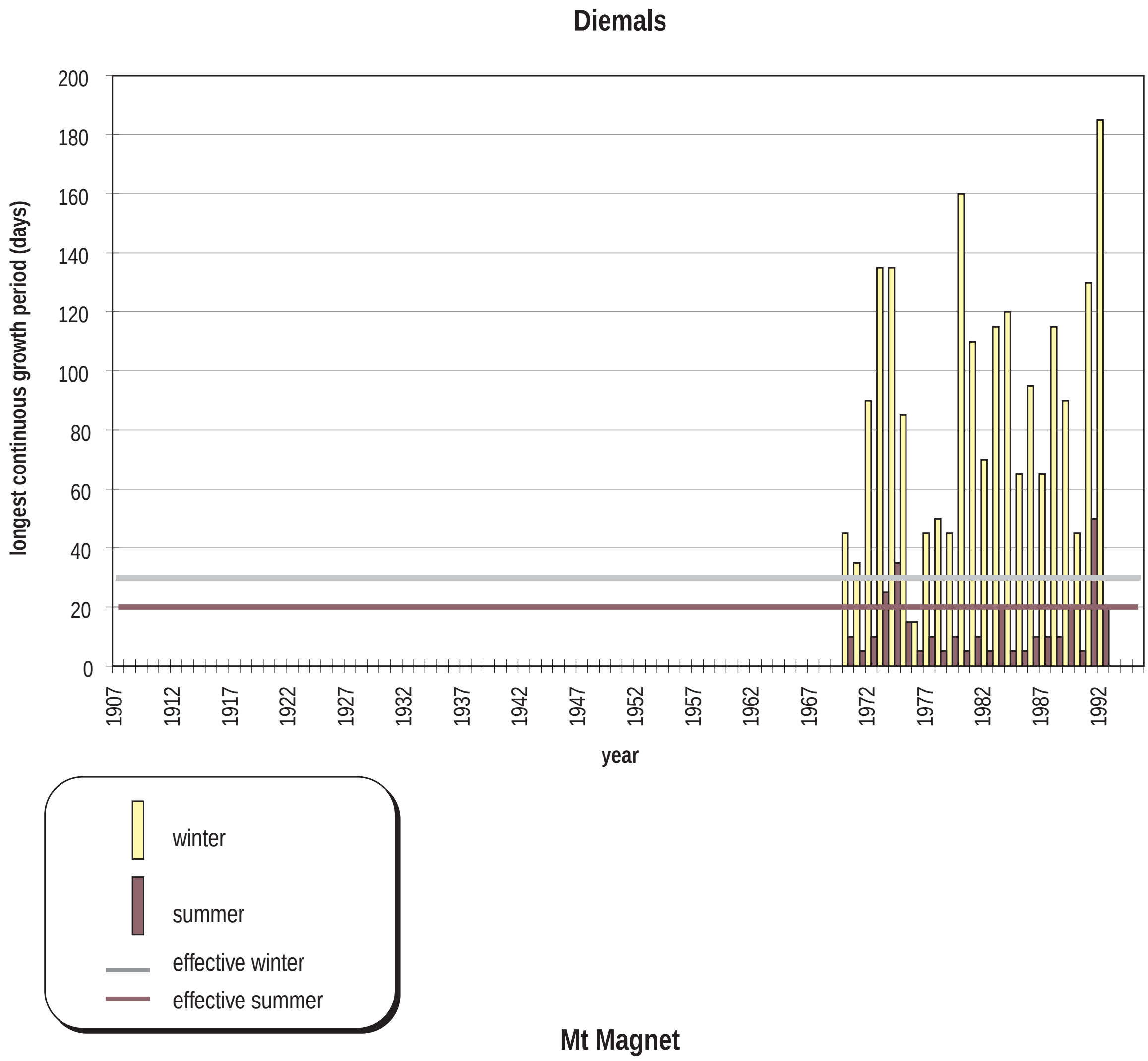
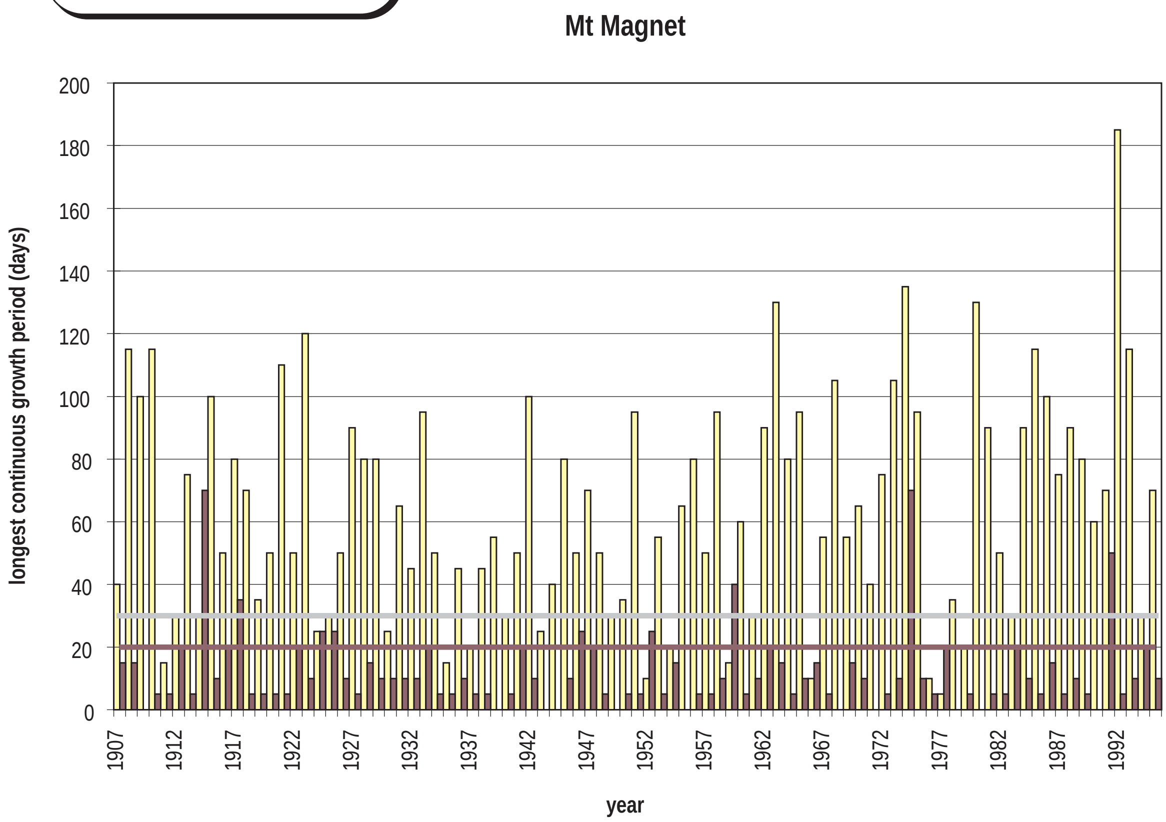


Figure 14. Annual longest continuous growth periods





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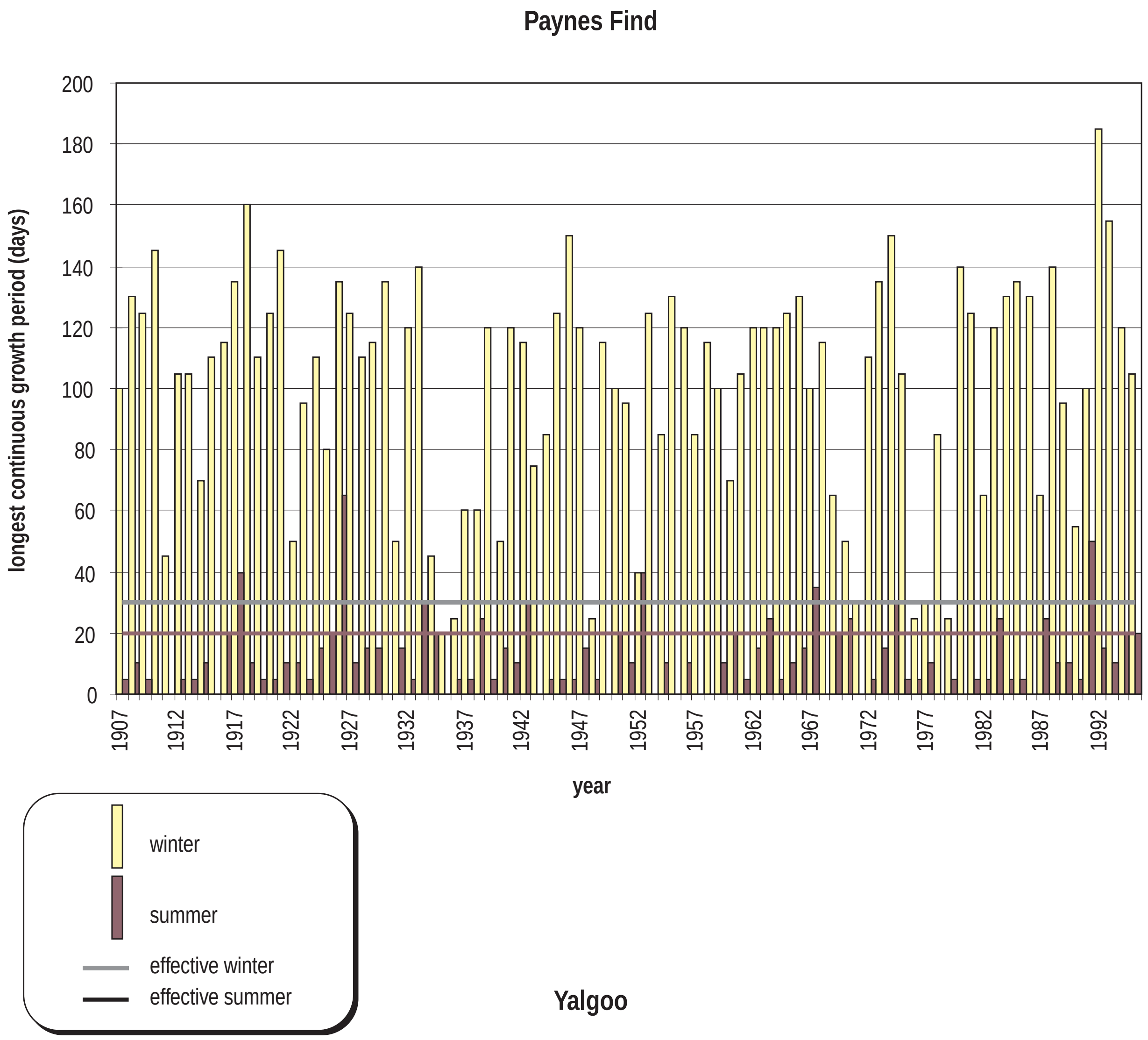

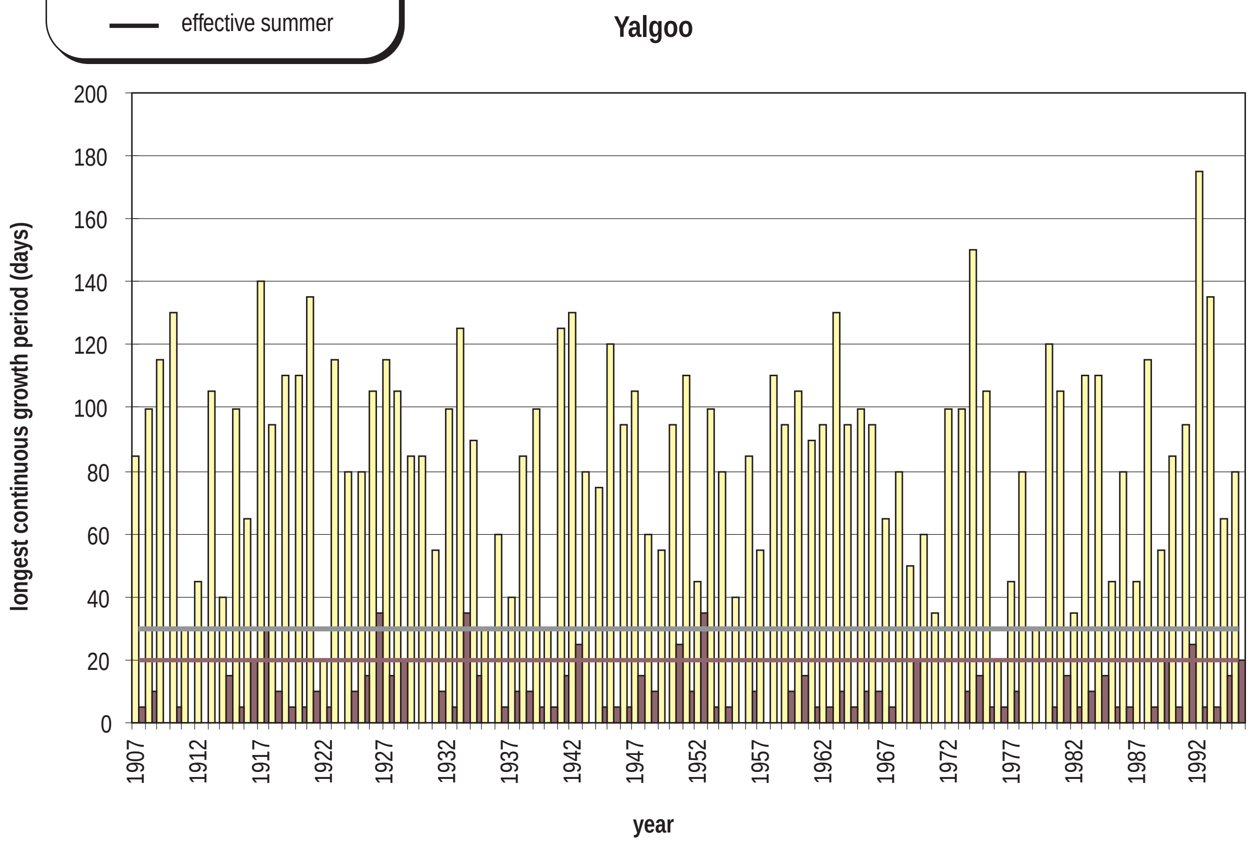

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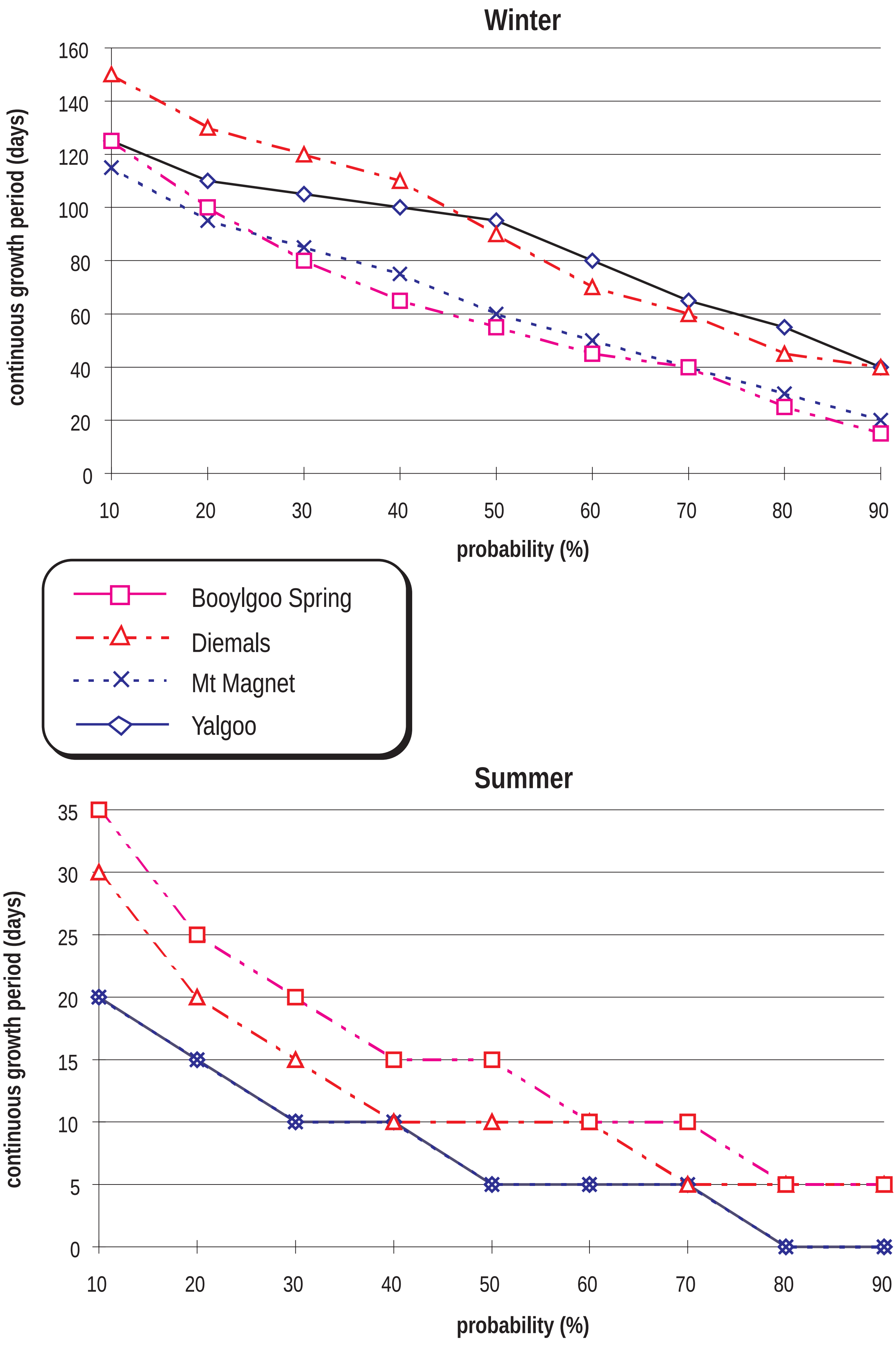

Figure 15. Winter and summer continuous growth period probability

Climate change

As with other arid and semi-arid regions, rainfall variability (reliability) is affected by the two to seven year cycle of the El Nino (which translates from Spanish as 'the boy-child' and relates to its appearance off Peru around Christmas) Southern Oscillation (ENSO) phenomenon. This is a natural phenomenon which co-exists with a natural greenhouse effect and both of which influence natural climate change. However, the earth's climate is known to be changing at an accelerated rate due to the influence of man. This change and the subsequent postulation of likely scenarios are engendering much current scientific debate. The causes of change are well documented and generally beyond the control of the ordinary citizen. Nevertheless all people will be affected by the consequences of mismanagement of the atmosphere, just as a price is extracted for mismanaging the land.

Computer climate models indicate that global climate change is likely to be complex and involve changes in atmospheric and oceanic circulations, with corresponding changes to sea level, daily temperatures and rainfall (State of the Environment Advisory Council (Australia) 1996). Using the 'Business-as-Usual' scenario adopted by the Intergovernmental Panel on Climate Change (IPCC) in 1990 the total levels of all greenhouse gases (carbon dioxide, methane, ozone, nitrous oxide and chlorofluorocarbons) in the atmosphere are expected to be double those of pre-industrial times just 200 years ago. The scenario to the year 2030 due to the enhanced greenhouse effect is:

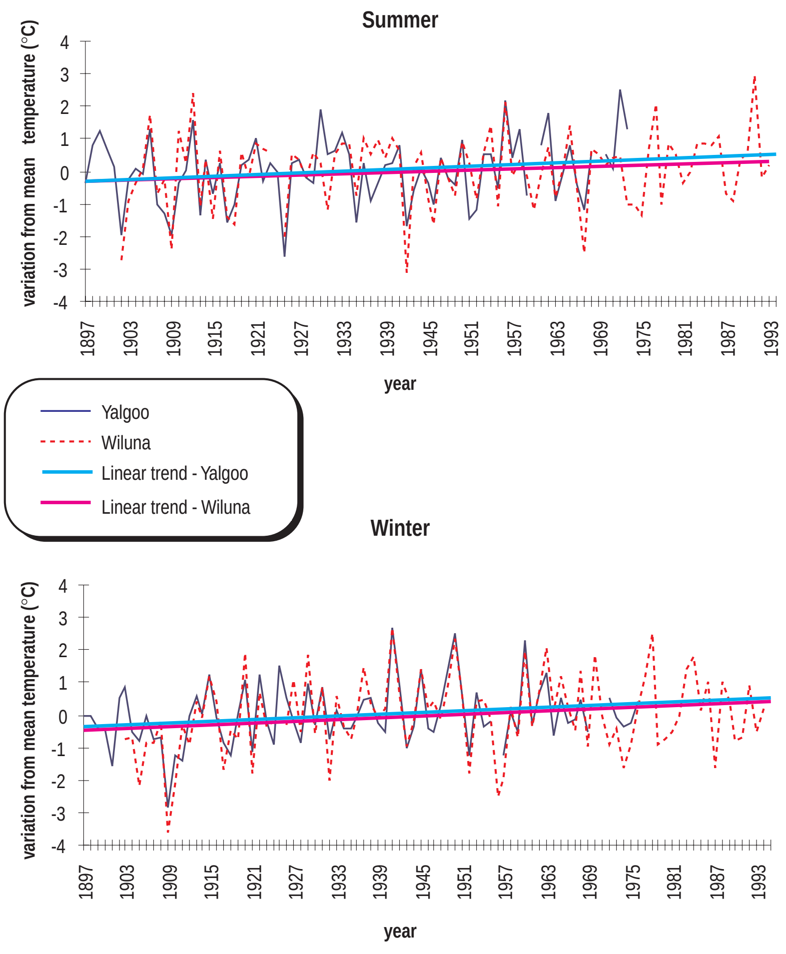

Figure 16. Winter and summer warming trends at two centres

- Temperature: Likely to rise between 1.5 and 4.5°C in the higher latitudes reducing to 2°C at the equator, however the oceans could be expected to retard this warming to a rate of about 0.3°C per decade.
- Sea-level: Raising the temperature of the oceans by 0.3°C is estimated to raise the sea-level by 20 cm. The reduction of the polar icecaps will alter the reflective properties of the earth's surface which will then further affect global temperatures.
- Rainfall: An increase up to 50% for areas deriving rain from (summer) tropical/subtropical monsoonal air. A decrease to 20% for areas receiving winter rain from the eastward passage of mid-latitude high and low pressure systems and associated fronts.
- Tropical cyclones: The southern limit of tropical cyclones is expected to shift approximately 200 to 400 km further south, and maximum intensity may increase by 30 to 60%.
- Wind: Speeds could decrease by 20% north of latitude 36°S due to changing north-south temperature gradients. In the southern half of the State there are likely to be fewer winter winds, and an increase in summer winds due to the lower passage of the anticyclone belt.
- Extreme events: There will be an increasing incidence of extremes such as floods, droughts, maximum wind gusts and severe storms. Damage to property, crops and soil will be more prevalent.
- Evaporation: This will be dependent on and proportional to any rise in temperatures. Rates may increase up to 15%.
- Ultraviolet (UV) radiation: The depletion of the upper atmospheric (stratosphere) ozone layer is expected to continue, thus allowing a greater amount of UV-B radiation to reach the earth's surface. It is estimated that (in Australia) a 1% loss of ozone will lead to a 2% increase in UV-B reaching the ground, which may lead to a 4% increase in skin cancers (Colls and Whitaker 1995). An increase in UV-B radiation is likely to be detrimental to vegetation.

Within the survey area there is evidence that weather patterns have changed in the past 100 years. Figure 16 graphs an increasing trend in summer and winter temperatures for Yalgoo and Wiluna (with the longest records) in the order of 0.5°C. This is consistent with a global warming trend identified by the IPCC of between 0.3 to 0.6°C, however they caution that such a trend is also of the same magnitude as natural climatic variability when the rate of temperature change between previous ice ages was 0.4°C per 100 years. (Steering Committee on Climate Change, p33, 1995).

"....because of the complexities in all the factors leading to weather and climate, no one will be able to predict when greenhouse conditions will commence. Only at some time in the future will we be able to look back and say unequivocally when, yes, the trend commenced.".....*Main 1991.*

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Geology and hydrogeology

S. L. Johnson

The Sandstone-Yalgoo-Paynes Find region is predominantly pastoral with open-range sheep grazing. It also is a minor mineral province, particularly in the north-east where there are about 20 operating gold mines and numerous prospects for nickel and uranium mine development.

The population is approximately 3,000 with most inhabitants living in and around the main towns of Yalgoo, Sandstone and Paynes Find. Small numbers also live on the pastoral stations and at small mining centres scattered through the area.

The availability of groundwater for stock is of major importance to the pastoral industry. It is also extremely important for town, mining and community water supplies, which use potable groundwater from various hydrogeological environments.

This section of the report aims to provide a regional overview of the nature and occurrence of groundwater resources from all available data held by the Water and Rivers Commission, and to assist in the location of groundwater supplies for the pastoral and mining industries.

Previous investigations

Detailed comments on previous geological investigations conducted by the Geological Survey of Western Australia (GSWA) are given in the relevant 1:250,000 Explanatory Notes (BARLEE -Walker *et al.* 1983, KIRKALOCKA – Baxter *et al.* 1983, NINGHAN – Lipple *et al.* 1983, PERENJORI – Baxter *et al.* 1985, SANDSTONE – Tingey 1985, YALGOO – Muhling and Low 1977, and YOUANMI – Stewart et al. 1983). Summaries of the geology in the Murchison Province (Watkins 1990), Western Gneiss Terrane (Myers 1990) and Southern Cross Province (Griffin 1990) are contained in Memoir 3, Geological Survey of Western Australia).

The earliest surveys investigated springs in the Tallering District (Brown 1871) and water supplies for mines and batteries in the Mt Magnet area (Jutson 1914). Regional reports on the hydrogeology and availability of groundwater are limited to the Mullewa District (Berliat 1957), the eastern portion of the study area (Morgan 1965), and the PERENJORI 1:250,000 hydrogeological map (McGowan 1991). The origin and hydrogeology of the groundwater calcrete in the eastern portion is described by Sanders (1969, 1973, 1974).

Various unpublished hydrogeological reports are held by the Water and Rivers Commission, on groundwater prospects for pastoralists, Aboriginal communities, the Main Roads Department, and town water supplies for Sandstone and Yalgoo. In addition, there are numerous confidential consultants' reports on the availability of groundwater for various mining projects.

Physiography

The study area is situated in the Yilgarn Craton and straddles the boundaries between two physiographic divisions: Swanland and Salinaland (Jutson 1950). Most drainage occurs within Salinaland, which is characterised by internal drainage into inland salt lakes such as Lake Moore and Lake Mason. A small north-western part is in Swanland, with westerly-flowing drainage towards the Indian Ocean.

The landscape is generally of low relief and characterised by large playa lakes occupying broad alluvial valleys between erosional escarpments (breakaways) of laterised bedrock highs. The direction of flow in these broad alluvial valleys or palaeodrainages, ranges from south-flowing in the west to south-east-flowing in the east. The relief of the outcrop areas is closely related to the underlying bedrock lithology, with granitoids typically forming large monoliths or flat pavements, whereas the greenstones form elongate subdued hills and rugged strike ridges.

Geology

Regional setting

Most of the area lies within the Murchison Province (Watkins 1990) of the Archaean Yilgarn Craton. The Murchison Province is bounded in the west by the Murgoo Gneiss Complex of the Western Gneiss Terrane (Myers 1990), and to the east by the Southern Cross Province (Griffin 1990). Overlying the basement rocks, in particular along the palaeodrainages, are alluvial, colluvial, aeolian, lacustrine and calcrete deposits of Cainozoic age (Figure 1). The generalised stratigraphy of the rock units with comments on their groundwater potential are given in Table 1.

Stratigraphy and structure

The Archaean rocks of the Murchison and Southern Cross Provinces comprise linear to arcuate, north to north-west-trending greenstone belts, which have been intruded by granitoid rocks (Figure 1). The greenstones occur beneath 40% of the area and contain metamorphosed and deformed sequences of mafic to ultramafic volcanic rocks, felsic volcanic rocks, and metasedimentary rocks, including cherts and banded iron-formations. Granitoid rocks occur beneath 60% of the area and comprise plutons of mainly equigranular to porphyritic adamellites, with minor occurrences of granite, gneiss and migmatite. The Murgoo Gneiss Complex consists of migmatite, banded-gneiss, and quartzite of Archaean age, and is believed to be derived from deformation of a coarse-grained granite (Myers 1990).

Most of the Archaean bedrock is largely obscured beneath a cover of Cainozoic deposits, which infilled the palaeodrainages during the early Tertiary. The palaeochannel sediments, where explored at Mt Gibson, have a thickness of up to 100 m and typically comprises an upper and lower sequence. The lower sequence generally comprises a basal, alluvial sand of Eocene age, which is confined by a plastic clay of lacustrine origin. The upper sequence of unconsolidated alluvium and calcrete has a variable thickness of up to 20 m thick, and reflects a slope-wash and valley calcrete environment. Colluvial deposits occur marginal to rock outcrops, and form a thin veneer over fresh and weathered bedrock. Lacustrine sediments of saline alluvium and gypsiferous clays form large claypans and playas, particularly within the main palaeodrainage systems, with marginal aeolian sand dunes.

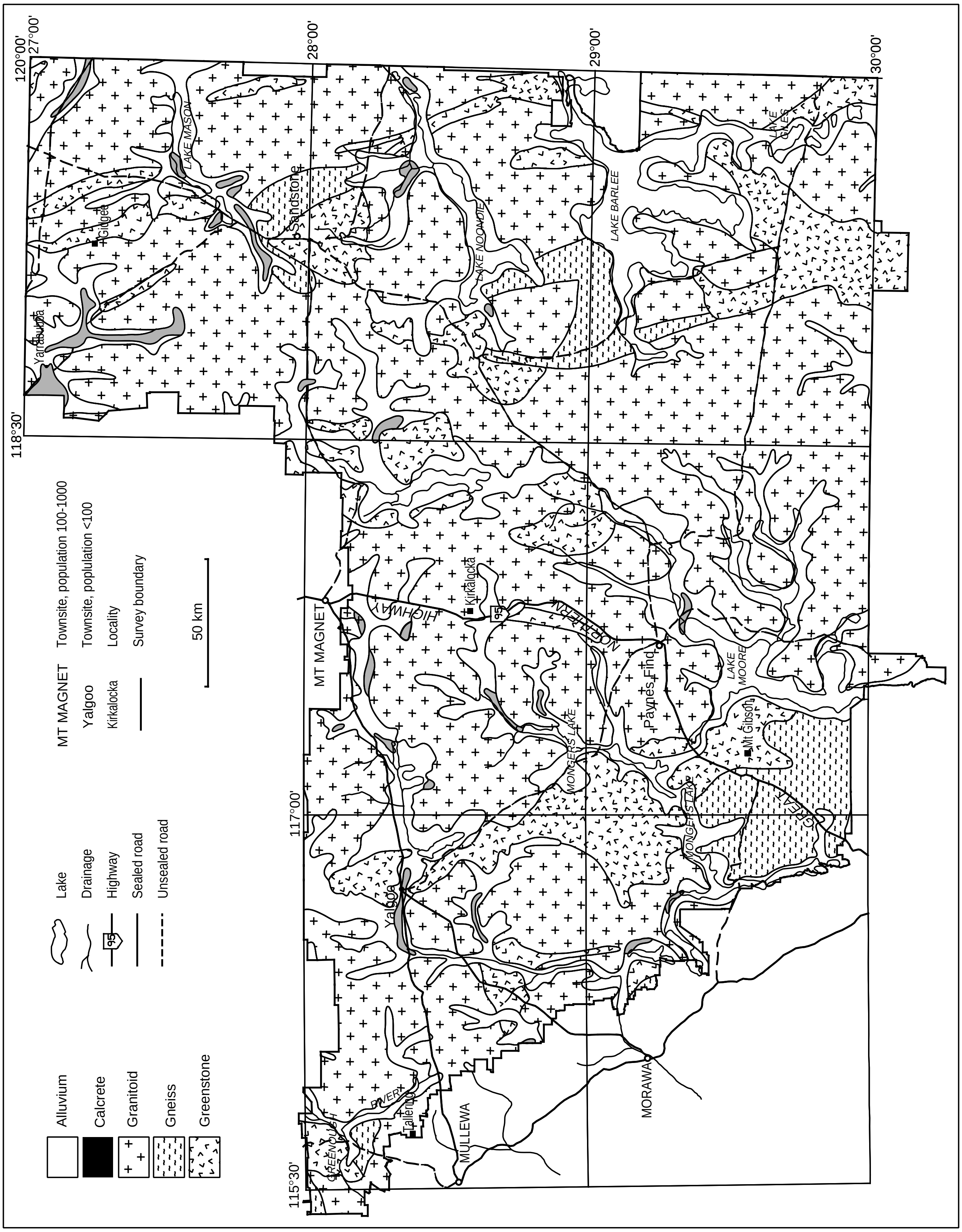

Figure 1. Generalised geology

Table 1. Generalised stratigraphy and hydrogeology

Age	Name	Lithology	Hydrogeology
Quaternary	Alluvium	Fine to coarse-grained sand with lenses of clay, silt and gravel	Major surficial aquifer in stream channels and palaeodrainages; fresh to saline groundwater; used for pastoral supplies
	Colluvium	Rock fragments, sand and silt	Minor surficial aquifer in scree slopes and outwash fans; fresh to saline groundwater; used for pastoral supplies
	Aeolian sand	Dunes of fine-grained to silty sand, and gypsiferous clay	Minor perched aquifer in marginal sand dunes; fresh to brackish groundwater; small supplies
	Lake deposits	Saline, gypsiferous clay and silt	Minor surficial aquifer in lake beds; saline to hypersaline groundwater; small supplies from sandy sections
Late Tertiary	Calcrete	Sheet calcrete	Major surficial aquifer in palaeodrainages; brackish to saline groundwater; large supplies
	Laterite	Massive, pisolitic laterite	Local perched aquifer beneath drainage divides; fresh to saline groundwater; small to moderate supplies
	Silcrete	Siliceous, vuggy to massive duricrust	Local surficial aquifer occurs as capping over ultramafic rocks; fresh to saline groundwater; large supplies
Early Tertiary	Palaeochannel deposits	Grey plastic clay overlying fine to coarse, carbonaceous, basal sands	Major confined sedimentary aquifer in palaeodrainages; saline to hypersaline; large supplies from palaeochannel sands
Archaean	Granitoids	Weathered and laterised, even-grained and porphyritic granitic rocks intruded by quartz veins and dolerite dykes	Minor local fractured rock aquifer in plutons; fresh to saline groundwater; moderate supplies from weathering profile and fractures
	Greenstones	Weathered and laterised, metamorphosed mafic to ultramafic volcanics, felsic volcanics, and metasedimentary rocks including cherts and banded iron-formations	Minor local fractured rock aquifer in linear, fault-bounded belts; fresh to saline groundwater; moderate supplies from fractures and shear zones, in particular cherts and banded iron formations
	Migmatite and gneiss	Weathered and laterised, foliated and deformed granitic gneiss rocks	Very minor local fractured rock aquifer in plutons; fresh to saline groundwater; small to moderate supplies from weathering profile and fractures

Hydrogeology

Source of data

The hydrogeological data used for this paper was obtained from detailed bore census carried out during regional geological mapping in the 1970s and 1980s. More than 1,000 bores and wells were sampled with all information (water levels, depths, yields and salinities) stored in AQWABase, the Water and Rivers Commission water point database. The distribution of all water points is relatively dense in the western half of the study area, in particular the localities of Yalgoo and Kirkalocka, but becomes progressively sparse towards the south-east (Figure 2).

Groundwater occurrence

Groundwater occurs throughout the Sandstone-Yalgoo-Paynes Find area. There is a regional watertable representing the level at which all pore spaces within rocks are saturated, and forms a subdued reflection of the topography. Although generally continuous, the watertable is sometimes absent in high areas where the weathered and fractured zone is unsaturated, or where the fractures are poorly developed.

Domestic and stock water requirements are generally met from small supplies of fresh to brackish groundwater in colluvium, valley-fill alluvium, and calcrete and calcreted alluvium. Colluvial deposits that border the main trunk drainages provide a reliable source of shallow, good quality groundwater with the salinity increasing towards the main drainage lines. From within the palaeodrainages, moderate supplies of brackish groundwater are obtainable from the shallow, permeable calcrete aquifer, and large reliable quantities of hypersaline groundwater are available from palaeochannel sands. Other smaller supplies are obtainable from the weathered bedrock profile, and from fractures and shear zones within the fresh bedrock.

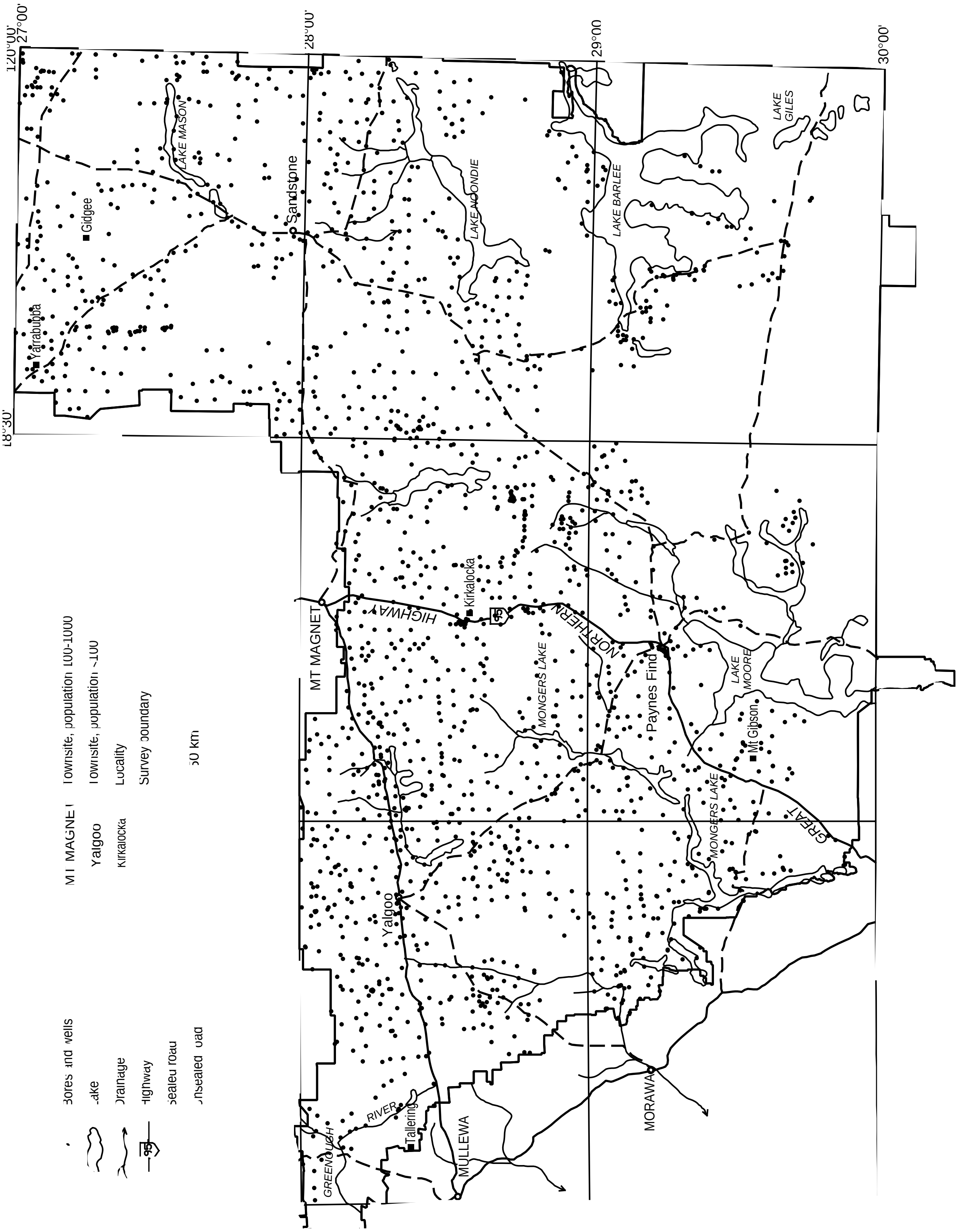

Figure 2. Bore and well distribution

Groundwater availability

Groundwater is essential to the pastoral and mining industry. The area has low rainfall with erratic seasonal distribution and high potential evaporation, hence a general surface water deficiency.

Throughout the area small supplies of fresh to brackish groundwater are suitable for stock-watering, however it is more difficult to locate large supplies of fresh groundwater for town supplies or irrigation. The location of large groundwater supplies, irrespective of salinity, depends on the presence of suitable groundwater-yielding rock types and site-specific geological conditions, such as the presence of fractures or shear zones.

Groundwater occurs in various hydrogeological environments, ranging from surficial and sedimentary aquifers with intergranular porosity, to weathered and fractured aquifers. The different aquifers are described below, and the relationship of groundwater within the various rock units and typical bore locations are shown in Figure 3.

Surficial aquifers

The main surficial aquifers include alluvium, colluvium, lacustrine and associated aeolian deposits, and calcrete.

• *Alluvium*

Alluvium, which forms the upper sequence of the Cainozoic stratigraphy within the palaeodrainages, generally consists of fine to coarse-grained quartz sand with lenses of gravel, silt, and clay. The thickness of alluvium ranges from about 5 to 20 m, depending on its location in the drainage system. Bore yields are likely to be highly variable, possibly up to 100 m^3/day, dependent on sorting and clay content. Groundwater salinity is also variable ranging from potable, such as utilised for the Mt Magnet town water supply (Ventriss 1993) north of the study area, to saline (greater than 7,000 mg/L TDS) in the lower reaches of the palaeodrainage systems.

• *Colluvium*

Colluvial deposits comprise outwash fans, talus and scree-slope deposits marginal to bedrock and extend downslope to the alluvial-filled palaeodrainages. The deposits range from less than 2 to 15 m in thickness, and consist of angular rock and quartz fragments in a matrix of brown silt and sand. Bore yields of less than 50 m^3/day are common, and supplies are generally better beneath the lower plains than higher on the scree slope (Laws, 1992). The watertable is generally less than 10 m below ground surface. Groundwater salinity is generally less than 2000 mg/L but tends to increase towards the main drainage lines. The groundwater salinity may vary depending on the underlying bedrock type, with the lowest salinity water occurring in colluvial deposits which flank granitoids, rather than those which flank the greenstone areas (Muhling and Low 1977).

• *Lacustrine and associated aeolian sediments*

The sediments of the playa lake systems consist of saline gypsiferous clay and silt with minor beds of sand, and are bordered by sand and kopi dunes. The lacustrine sediments are saturated by brine and due to their clayey nature are usually low yielding. The aeolian dunes may contain minor perched groundwater supplies overlying brine, and may yield up to 10 m^3/day of fresh to brackish groundwater useful for stock-watering.

• *Calcrete*

Calcrete is a carbonate rock formed by the in situ replacement of valley-fill debris by magnesium and calcium carbonate precipitated from percolating carbonate-saturated groundwater (Mann and Horwitz 1979). It generally occurs at the margins of present day salt lakes, and locally in some of the main sub-catchments in the palaeodrainages. Calcrete

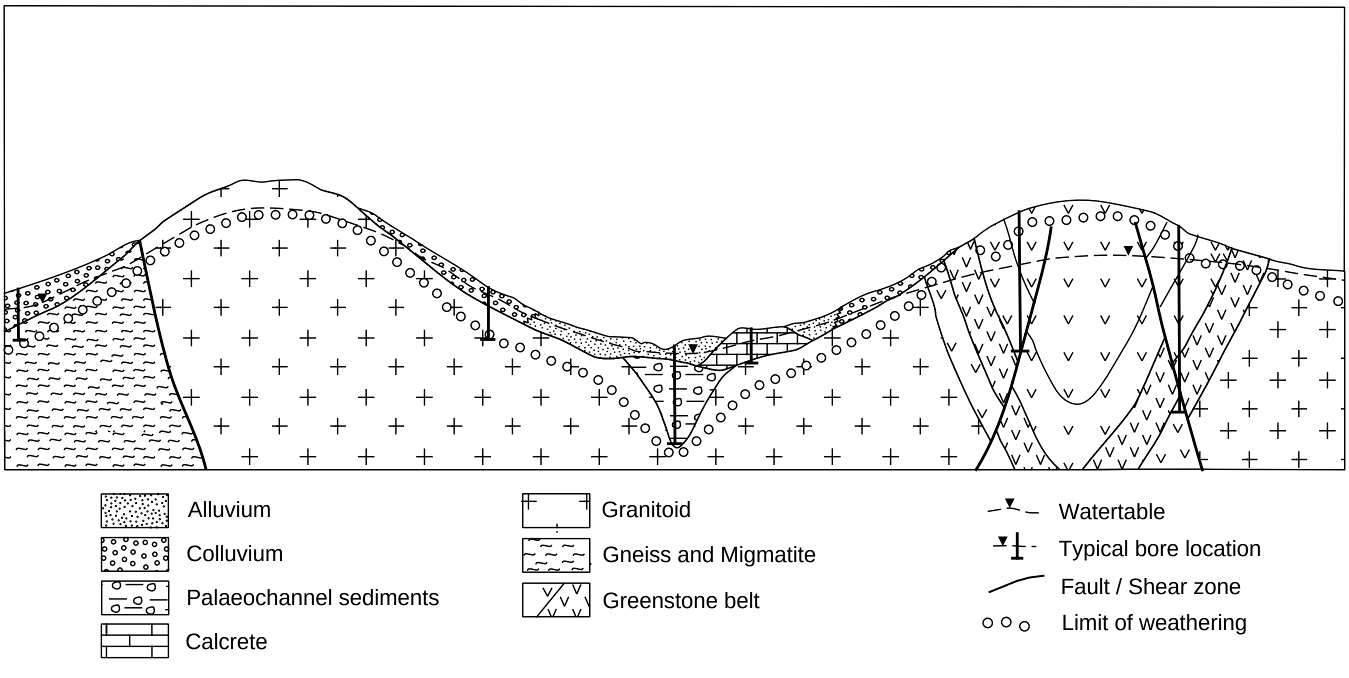

Figure 3. Schematic cross section showing groundwater occurrence and typical bore locations

bodies are generally less than 10 m thick, extend over areas of 1 km^2 to more than 100 km^2 such as near Yarrabubba Homestead. Karstic features such as sinkholes and gilgai structures are common with the calcrete aquifers.

Calcrete has a well-developed secondary porosity and high permeability, and forms an excellent aquifer with bore yields in excess of 1000 m^3/day. As calcrete is generally located in the lower reaches of the groundwater flow systems, it usually contains brackish groundwater between 2000 and 6000 mg/L TDS (Sanders 1969). There are small potable supplies, such as the proposed potable water supply for the Yeelirrie Uranium deposit (Australian Groundwater Consultants 1981) where the calcretes have good recharge due to runoff and are above the local base-level of groundwater drainage. In general, calcrete aquifers can provide readily obtainable, large supplies of brackish groundwater suitable for watering stock and mineral processing.

Sedimentary aquifers

The Tertiary sediments within the palaeodrainage systems are poorly documented throughout the area, however the stratigraphy and hydrogeology is likely to be similar to the Roe Palaeodrainage near Kalgoorlie (Commander *et al.* 1991). In the Mt Gibson Goldmine borefield, the palaeochannel comprises a basal, coarse to fine-grained, carbonaceous, alluvial sand which is overlain by a confining layer of dense, kaolinitic clay up to 40 m thick. The basal sands range in thickness from 10 to 40 m, and become thicker, broader and coarser downstream (Groundwater Resources Consultants 1988).

Bore yields from the palaeochannel sand aquifer in the Mt. Gibson borefield range from 100 to 1000 m^3/day, with yields increasing further downstream (GRC 1988). Groundwater salinity within the palaeodrainages increases downgradient of salt lakes from 30,000 mg/L to over 100,000 mg/L TDS. The aquifer in the north-eastern Goldfields is capable of producing large and consistent yields. However the palaeochannel aquifer is poorly explored in the survey area and its usefulness is mainly restricted to the mining industry by its hypersalinity.

Fractured rock aquifers

The main fractured rock aquifers are the extensive granitoid rocks throughout most of the area; the gneisses and migmatites of the Murgoo Gneiss Complex in the west, and the greenstone belts.

- *Granitoid*

Granitoid rocks consist of even-grained to porphyritic granite and adamellite. They are laterised and deeply weathered, up to 30 m thick, and characterised by a thin duricrust or silcrete over a variable thickness of sandy kaolinitic clay. This weathering profile has developed through the chemical breakdown of the crystalline bedrock during Tertiary and Quaternary times. Groundwater can be generally obtained from the quartz-rich grit at the base of the weathering profile, although some may also be present in open joints and fractures within the upper 5-10 m of fresh bedrock.

Bore yields from the weathering profile are generally small, up to 100 m^3/day, although larger supplies may be available from lineaments, faults or shear zones within the fresh bedrock. However, large supplies are often difficult to locate in the granitoids because of their homogeneity and generally sparse fracturing. The salinity of the groundwater ranges up to 5,000 mg/L TDS with less saline water occurring along the drainage divides, and higher towards the drainage lines.

Bore depths are highly variable ranging from 5 to 45 m below ground level. They depend on the site location within the topography with the maximum depths occurring along drainage divides.

- *Gneiss and migmatite*

Groundwater in the Murgoo Gneiss Complex generally occurs within the weathered profile, which has a high clay content, but the gritty layer found at the base of the granitoid weathering profile, is generally absent. As a result, supplies are usually less than 10 m^3/day with salinities generally ranging between 1,000 and 7,000 mg/L TDS, although less saline water can be obtained beneath drainage divides.

- *Greenstone*

The greenstones comprise mafic and ultramafic volcanics, felsic volcanics, volcaniclastics and metasedimentary rocks, including cherts and banded iron-formations. They occur in major north-south trending belts throughout the study area. Locally, these rocks have a deep weathering profile which consists predominantly of dense clay, except over ultramafics which are capped by a vuggy silcrete.

Small groundwater supplies are generally obtainable from near the base of the weathered zone and in the immediately underlying fractured rocks. Large supplies of up to 1,500 m^3/day have been obtained from bores, up to 100 m deep, located within highly fractured and sheared basalts, cherts and banded iron-formation (AGC Woodward-Clyde 1995). Salinity generally ranges from 200 to 4,000 mg/L TDS beneath catchment divides, however values in excess of 15,000 mg/L TDS have been obtained in low-lying areas.

Groundwater resources

There is insufficient data to enable a detailed assessment of groundwater resources in the study area. An approximation of the resources within the calcrete and palaeochannel sand aquifers can be made from limited hydrogeological data, however no meaningful estimations of resources within the alluvium, colluvium, and weathered and fractured bedrock are possible.

As annual recharge from rainfall is very small, resources are considered in terms of groundwater held in storage. Only a proportion of this groundwater is economically recoverable.

Calcrete aquifers contain the largest resources with the salinity generally less than 7,000 mg/L TDS, and hence are the best source of large, fresh to brackish quality supplies. Groundwater storage in the shallow calcrete aquifers throughout the area is estimated at 874 million m^3, assuming a saturated thickness of 10 m and specific yield of 0.15. Investigations at the proposed Yeelirrie uranium deposit in the north-eastern corner of the area, estimated a commandable groundwater resource of 208 million m^3 with salinity ranging from 1,000 to 6,000 mg/L TDS (Australian Groundwater Consultants 1981). Groundwater resources within the calcrete tend to increase towards the north-east, as calcrete is poorly developed south of 29°00’S.

Tertiary sedimentary rock aquifers, in particular the basal palaeochannel sands, contain large quantities of saline to

hypersaline groundwater. Groundwater resources in the palaeochannel sand aquifer throughout the area are estimated to be at least 0.4 million m^3/km of channel length, assuming a channel width of 100 m, saturated thickness of 20 m and specific yield of 0.2, giving a total of approximately 420 million m^3 of groundwater in storage for an aggregate channel length of 1,040 km. These values are considered conservative, when compared with palaeochannels in the Roe Palaeodrainage (Commander *et al.* 1991). The groundwater resources within the Mt Gibson palaeochannel have not been estimated, however the five production bores were reported to have an aggregate yield of 0.7 million m^3/yr in 1988 (Groundwater Resource Consultants 1988).

Small to moderate supplies of fresh to saline groundwater suitable for stock can be obtained from alluvial and colluvial deposits, however they are saturated only in the low-lying areas where they are thickest. It is therefore difficult to reliably estimate their groundwater resources. The specific yield of these sediments is probably less than 0.05 owing to the high clay content, and it is likely that the commandable groundwater resources are less than 10% of the total groundwater resources throughout the area.

The potential groundwater resources in the fractured granite-greenstone bedrock is very difficult to estimate reliably on a regional scale because of the localised and discontinuous nature of fracture systems. This variability limits the extent of groundwater storage in fractured rocks. Groundwater resources in the weathered and fractured bedrock probably represents about 5% of the total groundwater resources of the area, as specific yield is generally between 0.001 and 0.005 (Kern 1996).

Groundwater salinity and quality

Distribution of salinity at the watertable is shown by isohalines in Figure 4, although may also increase with depth below the watertable. Where information is limited, the salinity is inferred. Areas with less than 1000 mg/L TDS (Figure 4) represent fresh or potable groundwater, 1,000 to 3,000 mg/L TDS – good stock-quality water, 3,000 to 7,000 mg/L TDS – marginal stock-quality water, and greater than 7,000 mg/L TDS – saline groundwater.

Regional distribution indicates an increase in salinity towards the drainage lines, particularly the palaeodrainages, with the lowest salinity groundwater occurring along the drainage divides. The most saline groundwater (>14,000 mg/L TDS) occurs along the palaeodrainage systems, with the groundwater salinity increasing downstream of the salt lakes due to the concentration of salts through evaporation at lake surfaces. Local areas of fresh to brackish groundwater occur in sand and kopi dunes around and between salt lakes as a result of local recharge (Allen 1996).

The only groundwater analyses conducted in the area are from Water Corporation monitoring of town water supplies at Sandstone and Yalgoo, and groundwater consultant's reports on mine water supplies (Table 2). Groundwater throughout the area is sodium chloride type, reflecting its derivation (through precipitation) from cyclic salts. The groundwater from calcrete is generally harder than water from other sources, however high levels of hardness have been recorded in water from alluvium, colluvium, and greenstones.

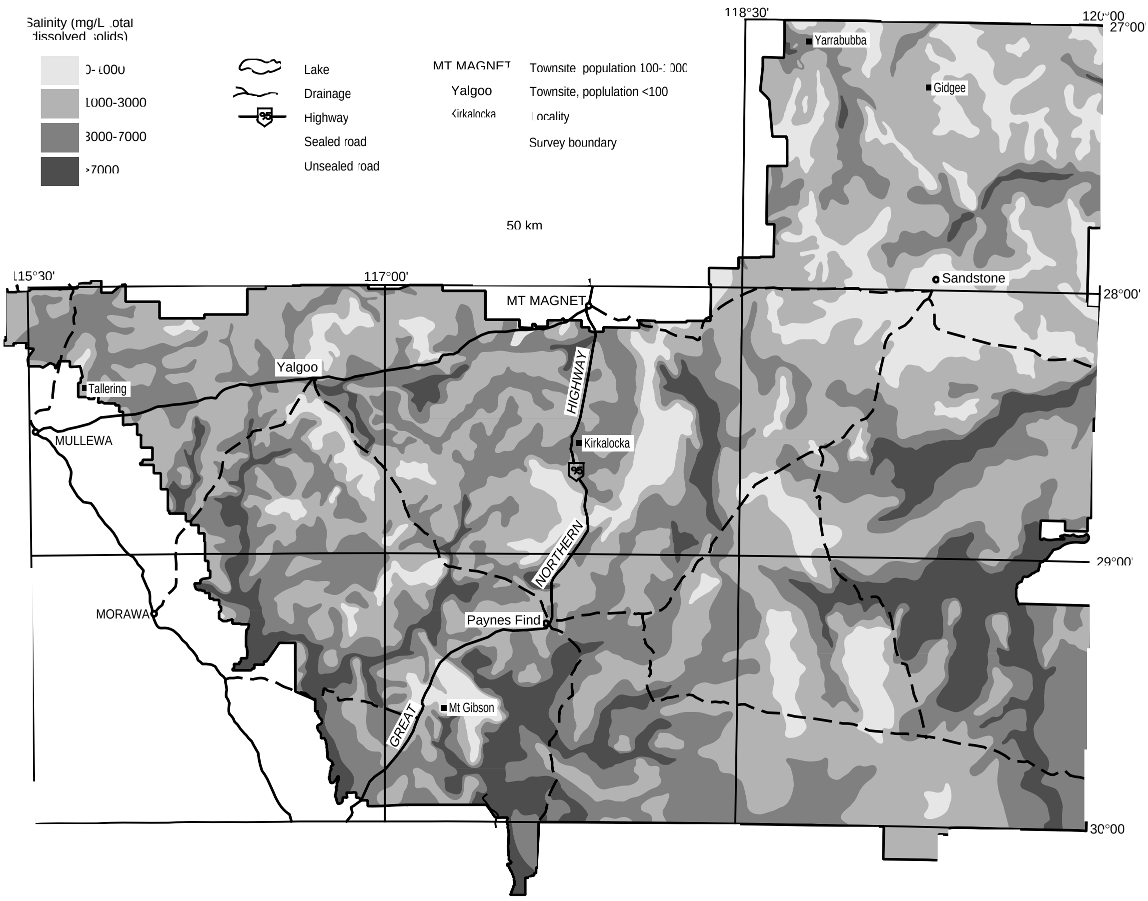

Figure 4. Distribution of groundwater salinity

Table 2. Selected chemical analyses (mg/L) of groundwater

	Sandstone	Yalgoo	Mt Magnet (north of area)	Yeelirrie	Gidgee gold mine	Mt Gibson gold mine
Wellfield (and aquifer)	Pix Shaft (fractured greenstone)	Carlaminda (weathered and fractured granite)	Genga (alluvium, calcrete)	Potable (calcrete)	Wedge (fractured quartz veins)	Process (palaeochannel sands)
DEPTH (m)	>100	60.2-70.3	29.5-71.6	25-79	82-109	38.0-67.0
SWL (m)	67-72	15.2-15.9	8.6-10.4	3.1-21.0	15.7-17.4	9.3-24.6
pH	n/a	7.4-7.8	7.7-8.1	7.4-7.6	7.7-7.8	7.2-8.6
TDS	1380	846-1002	557-612	1700-3100	855-910	4018-52671
Hardness	426	348-367	214-251	280-560	295-310	620-12512
Alkalinity	165	189-194	176-188	n/a	n/a	253-589
Ca	67	42-43	32-38	20-35	63-67	56-230
Mg	63	59-63	32-38	20-75	34 -38	137-1945
Na	294	153-174	137-158	210-330	170 -175	1171-16530
K	n/a	7-8	8-10	20-35	8.5 -14	14-285
HCO_3	n/a	n/a	215-229	145-200	123-129	238-580
Cl	485	275-321	174-191	335-620	255-260	1865-30040
SO_4	n/a	54-61	50-60	120-265	125-170	336-3780
NO_3	82	17-20	51-64	35-45	65-75	1-47
SiO_2	n/a	66-81	64-78	60-65	n/a	n/a

n/a - not available

High levels of sulphate, such as in the Wedge deposit at Gidgee gold mine (AGC Woodward-Clyde 1995), are largely related to sulphide mineralisation within the ore body. Nitrate levels are also high throughout, generally exceeding the National Health and Medical Research Council guidelines (45 mg/L) for drinking-water standards (1987). The source of nitrate is related to nitrate-fixing bacteria associated with soil crusts and termite mounds and to nitrate-fixing vegetation (Allen 1996).

Potential groundwater development

Pastoral industry

The pastoral industry is one of the major users of groundwater with about 1,000 bores and wells constructed throughout the area. Their distribution has been dictated more by the paddock system, rather than by the availability of groundwater. Therefore most tend to be concentrated in the low-lying areas of alluvium rather than the topographically higher, colluvial soils, or areas of bedrock outcrop. In general, groundwater supplies are easily located, but many exploratory sites have been abandoned due to drilling problems, inadequate supplies, or unacceptable salinity.

Most bores and wells used by the pastoral industry are less than 30 m deep and are typically equipped with windmill which yield up to 10 m^3/day. Larger supplies in excess of 20 m^3/day are available from areas of calcrete and thick alluvium. Groundwater with salinity up to 7,000 mg/L TDS can be used for stock-watering. Domestic supplies usually rely on rainwater tanks supplemented by potable groundwater, if available.

Town water supplies

The towns of Sandstone and Yalgoo obtain most of their potable water from the ground. The Sandstone water supply is obtained from the Pix Shaft west of the townsite in weathered and fractured greenstone rocks. Total abstraction in 1985-86 was 19 000 m^3/year with a marginal groundwater salinity of 1,500 mg/L TDS (Water Authority of Western Australia 1987). Nitrate levels exceeded National Health and Medical Research Council guidelines for drinking-water standards (45 mg/L) and the water is also very hard.

The Yalgoo supply is obtained from a wellfield near Carlaminda Homestead, in weathered and fractured fresh bedrock of greenstones and granitoids. In 1992-93 abstraction was 33,000 m^3/year with salinity ranging from 800 to 1,050 mg/L TDS (Water Authority of Western Australia 1994), and nitrate levels which exceed guidelines for infant consumption (National Health and Medical Research Council, 1987).

Mining industry

A number of large mining projects, particularly gold, occur in the east of the area. The mining industry requires groundwater for mineral processing, camp water supplies and dust suppression. In most instances, there is also a need for dewatering prior to commencement of mining (Allen 1996).

Water for mining has been obtained from a variety of hydrogeological environments, and includes fractured and jointed quartz veins (Plutonic Limited, Gidgee gold project; Mackie Martin and Associates 1986); palaeochannel sands (Mt Gibson gold project; Groundwater Resources Consultants 1988); and calcrete (Yeelirrie Uranium Project; Australian Groundwater Consultants 1981). Groundwater

yields of up to 1,300 m^3/day are obtainable from the fractured-rock and calcrete aquifers, compared with sustainable yields of 300 to 900 m^3/day from the palaeochannel sand aquifer. The groundwater salinity ranges from 900 to >40,000 mg/L TDS with less saline groundwater present in the fractured-rock aquifers.

Conclusions

The Sandstone-Yalgoo-Paynes Find area is semi-arid to arid with a variable, unreliable rainfall and high evaporation rates. Hence, groundwater resources are the most readily obtainable and reliable source of water for the pastoral and mining industries.

The quality of groundwater is generally suitable for stock with the lowest salinity usually occurring beneath catchment divides and the highest along the palaeodrainages. Groundwater in the palaeodrainages is typically saline to hypersaline, and is used by the mining industry for ore treatment and extraction. Domestic supplies on pastoral leases are usually met from the collection of rainwater, while town supplies in Yalgoo and Sandstone are positioned in well-elevated, fractured bedrock aquifers.

Small supplies, less than 10 m^3/day, of variable salinity groundwater are available throughout the region, but larger supplies are generally restricted to specific aquifer types such as calcrete, thick alluvium and palaeochannel sands. In addition, large supplies of groundwater are available from specific locations including shear zones in fractured rocks and the base of the weathering profile in granitoid rocks. Large fresh supplies are rare, but brackish to hypersaline supplies are more readily available.

The pastoral industry uses a small percentage of groundwater held in storage, and there is considerable scope for further development of these resources. Due to the nature of the aquifers and their episodic recharge, they will have to be carefully managed to ensure quality and quantity of the resource is not compromised.

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Regional vegetation

A.M.E. Van Vreeswyk

Botanical districts

About 90% of the survey area lies in the Austin botanical district of the Eremaean Botanical Province (Figure 1). The western edge of the survey area runs closely along the boundary between the Eremaean Province and the South-West Botanical Province (Beard 1990). Small parts of the survey area fall within two botanical districts of the South-West Botanical Province: the south-western corner lies in the Avon botanical district and a very small area in the far north-west falls in the Irwin botanical district. The extreme south-east of the survey area falls within the Coolgardie botanical district of the South-Western Interzone.

Vegetation formations

In 1976 Beard mapped the major structural vegetation formations within Western Australia at 1:1,000,000. The survey area falls on the Murchison map sheet. Figure 2 shows a generalisation of the vegetation formations mapped within the survey.

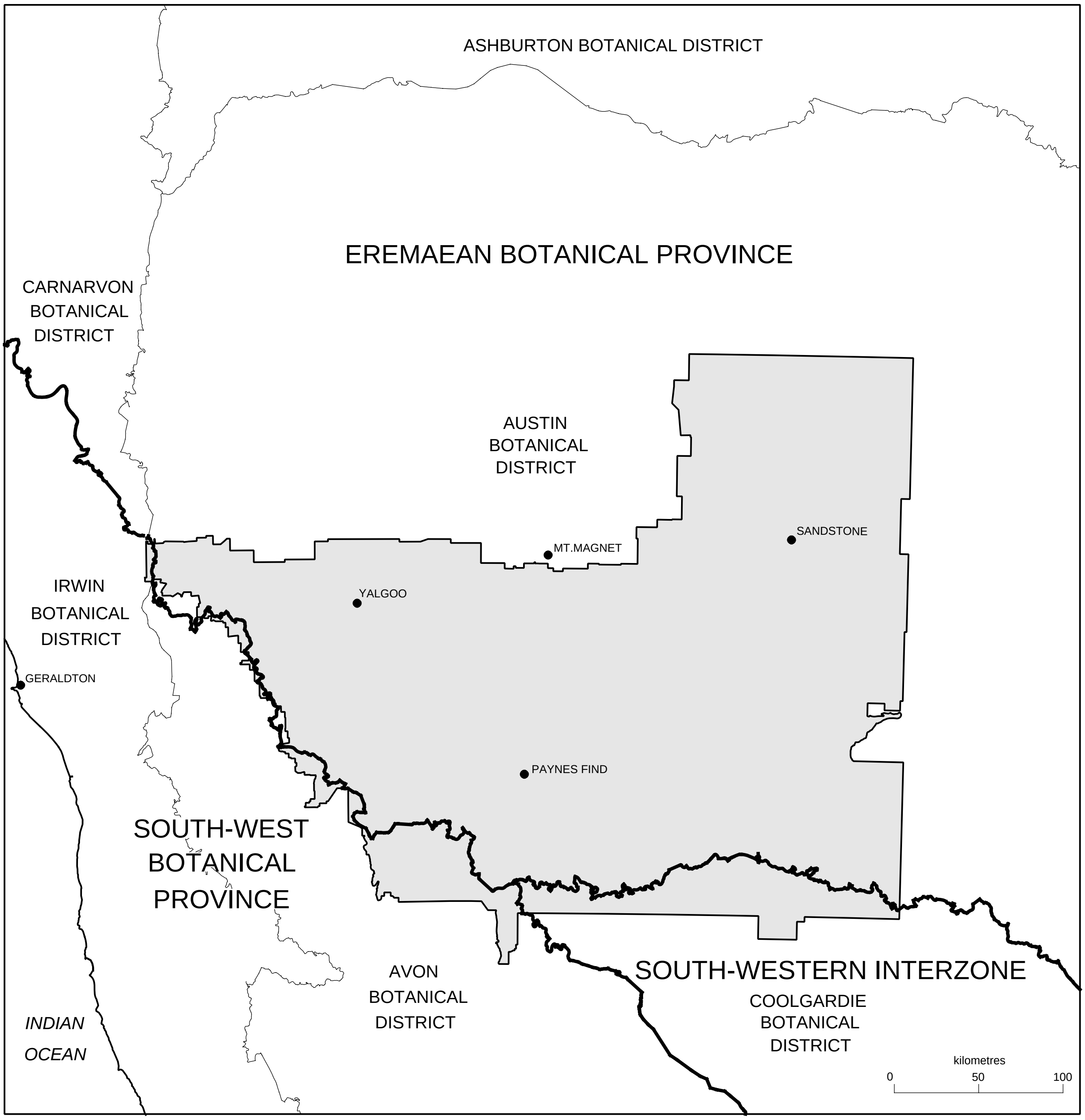

Figure 1. The botanical provinces and their districts within the survey area (after Beard 1990)

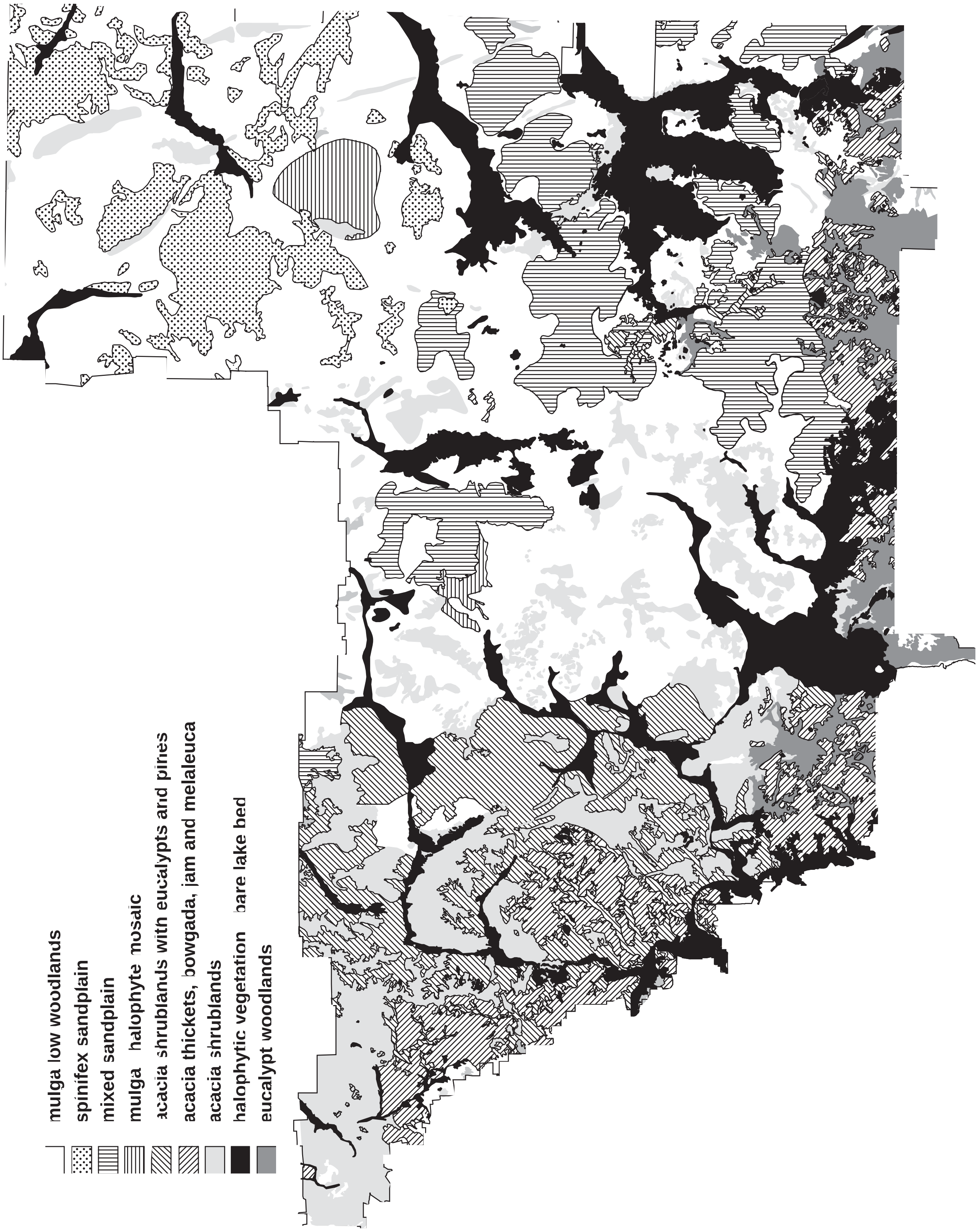

Figure 2. Generalised vegetation formations within the survey area (after Beard 1976).

Eremaean Botanical Province

In the north-east the predominant vegetation formations are mulga (*Acacia aneura*) low woodlands or tall shrublands associated with red loams over siliceous hardpan and scattered mulga and mallee (*Eucalyptus kingsmillii*) over spinifex hummock grasslands on gently undulating sandplain.

Between Mt Magnet and Paynes Find, and across to the south-east, mixed communities on sandplain replace spinifex hummock grasslands as the co-dominant vegetation formation with mulga low woodland. In the central area this mixed sandplain consists of bowgada, heath and spinifex, and in the east of mallee, spinifex and heath, the dominant mallee being *Eucalyptus oleosa*. Sandplain with mallee, wattles, spinifex and patches of heath occurs south-west of Lake Barlee. These mixed sandplain communites indicate the transition into the South-Western Interzone with associated soil and climatic gradients. South of the Kirkalocka map sheet the mulga low woodlands are replaced by mulga and bowgada communities with scattered cypress pines (*Callitris glaucophylla*).

Around Sandstone and Youanmi station there are mosaics of mulga low woodland and saltbush and bluebush shrubland associated with greenstones. This mosaic also occurs around Kirkalocka station.

In drainage lines on the western side of Lake Barlee there are bowgada (*Acacia ramulosa*) and jam (*A. acuminata*) shrublands with scattered York gum (*Eucalyptus loxophleba*). There are minor areas of acacia and pine low woodland, bowgada shrubland, bowgada and jam shrubland and jam thicket in the central area.

To the east of Lake Moore, mulga, York gum and cypress pine low woodlands are prominent. Bowgada with pines and eucalypts occur along the boundary with the South-Western Interzone.

In the south-west there is a transition between the Eremaean and the South-West Provinces. With the increase in rainfall and the shift to predominantly winter falls, mulga is gradually replaced in a south-westerly direction by other acacias. The vegetation becomes lower and denser. On the extreme south-western edge of the survey area, adjacent to the South-Western Botanical Province, bowgada, jam and *Melaleuca uncinata* thickets are dominant and acacia shrublands with scatttered eucalypts or cypress pine in drainage lines. Eucalypts may be York gum or York gum and *Eucalyptus oleosa*. The acacia shrublands may be dominated by bowgada, or by bowgada and jam.

Throughout the Eremaean Province there are localised areas of acacia shrublands associated with greenstone ranges, such as Montague Range, Booylgoo Range, Johnston Range and Gnows Nest Range. They are dominated by mulga or mulga and granite wattle (*Acacia quadrimarginea*).

Halophytic vegetation, associated with salt lakes, occurs throughout the area in the Eremaean and South-West Provinces. The highly saline lake beds are bare or support samphire (*Halosarcia* spp) communities. The fringing saline plains support saltbush and bluebush (*Atriplex* and *Maireana*) shrublands with scattered acacias. Dominant acacia species include mulga, *Acacia sclerosperma*, prickly acacia (*A. victoriae*), snakewood (*A. eremaea*), bowgada and jam. On the boundary between the Eremaean and South-West Botanical Provinces the community becomes melaeucas thickets with samphire.

South-West Botanical Province

The part of the survey area within the South West Province is dominated by woodlands on red loams on lower ground and acacia thickets on yellow sandy soils with gravel on higher ground. The eucalypt woodlands are dominated by York gum, or York gum and salmon gum (*Eucalyptus salmonophloia*) on heavier soils. The acacia thickets commonly contain numerous species but may be dominated by jam.

South-Western Interzone

The survey area within the South-Western Interzone is dominated by York gum and salmon gum woodlands and acacia thickets. The acacia thickets contain numerous acacia species.

On the north of the Diehardy Range the acacia thicket is dominated by mulga and granite wattle. There are also minor areas of mulga low woodland, bowgada shrubland with scattered black oak (*Casuarina pauper*) trees, *Casuarina campestris* thicket and eucalypt and pine low woodland. *Dryandra arborea* occurs on the crest of the Diehardy Range, which is composed of banded ironstone ridges. On the northern slopes of the range the vegetation is Eremaean (open acacia shrubland), and on the southern slopes the vegetation is South-Western (dense thicket of mainly *Casuarina acutivalvis* and *C. campestris*).

Major vegetation formations and plant communities encountered during the survey are discussed in the Vegetation chapter. Habitats at plant community/landform/soil type scale have been identified and are described in the Ecological Assessment chapter.

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Declared plants and animals

M. Dowd

The following summaries describe certain plants and animals in the survey area which have been declared under the Agriculture and Related Resources Protection Act 1976. The Act is administered by staff of Agriculture Western Australia, and all plants and animals that have been declared are required to come under some degree of control. This varies from ‘barrier quarantine’, which means eradication from an area, to the lesser category of ‘control and containment’, which involves reducing numbers and prevention of spread.

The number of introduced plants which have weed potential in the area are limited to types adapted to long periods of low soil moisture and tolerant of high day temperatures. In general they pose much less threat to the pastoral industry than do the vertebrate pests described later.

All declared plants in the survey area have been introduced by human activity such as in hay and fodder, stuffing for various saddles and harnesses, along railway lines and as household plants. The spread of these plants has been assisted by periodic flooding, wandering stock, native and feral animals, vehicles and road works.

Weeds

Gorteria *(Gorteria personata)*

The only known infestation occurs on Karara station in the Perenjori Shire.

Ecology

Gorteria is an annual plant germinating in winter and flowering in the late spring. The burrs fall to the ground and may be carried by animals, on wool or on machinery. Seeds may remain dormant in the soil for several years.

Significance and management

This can compete with the more valuable pasture plants. The dry seed heads have very tough spines which could cause severe vegetable fault in wool. The plant is in the eradication category but the size of the infestation on Karara station makes this unrealistic. The significance of the infestation is being evaluated.

Mexican poppy *(Argemone ochroleuca)*

Occurs on Yoweragabbie station near Mt. Magnet.

Ecology

Mexican poppy is a winter growing annual to 1 m in height. Although a member of the poppy family, it resembles a thistle prior to flowering.

Significance and management

Mexican poppy is poisonous to stock, but few deaths occur under field conditions because the spiny plant is not readily eaten (Everist 1981). Some stock have died after eating contaminated hay or chaff and the possibility of contamination is its main cause for concern. Mexican poppy is in the containment category. The infestation is being monitored and if it shows signs of spreading control measures will be implemented.

Parkinsonia *(Parkinsonia aculeata)*

An isolated infestation on Windimurra station in the Mt. Magnet Shire was last recorded in 1992.

Ecology

Introduced as a shade and ornamental tree, it is capable of forming dense thickets of thorny shrubs which impede stock mustering, reduce grazing and may even prevent stock access to water. Competes with native plants, particularly close to creeks and rivers.

Significance and management

Parkinsonia is not a declared plant south of the 26th parallel. However isolated infestations have occurred and all efforts made to eradicate the plant.

Patersons curse *(Echium plantagineum)*

Roadside infestations have been recorded on the North West Coastal Highway and around the Paynes Find settlement. Other infestations occur on the Mt. Magnet to Geraldton road.

Ecology

Patersons curse is more common in undergrazed sheep pasture in the higher rainfall agricultural areas. It is a bristly annual plant which usually germinates in early autumn and produces numerous attractive purple flowers. It is spread by seed, which may be carried on stock and in their digestive tracts, or in hay and fodder.

Significance and management

Patersons curse is a pasture weed in the medium rainfall agricultural areas where it can grow very densely and provide severe competition for the more useful species. It causes liver damage and ultimately death of stock if grazed for prolonged periods (Everist 1981). However, no reports of poisoning have been received in WA. It is unlikely to become a serious problem in the survey area.

Saffron thistle *(Carthamus lanatus)*

Saffron thistle is a common troublesome plant covering many hectares of pastoral country and water courses in the Mt. Magnet Shire and to a lesser extent in the Yalgoo Shire. Infestations also occur along main roads.

Ecology

Saffron thistle is an unpalatable winter growing annual which establishes only from seed. Seed dormancy is up to at least eight years which makes control very difficult.

Significance and management

It is a prolific seed producer with ability to colonise areas to the exclusion of more desirable plants. Seed head and vegetable matter contaminate the wool and interfere with shearing and downgrade the wool value. Infestations on road

verges are treated annually by Agriculture Western Australia staff and costs are recovered from the Main Roads Department. Infestations within town reserves are also treated annually because of the possibility of transfer by machinery or vehicle to pastoral lands. To date spread onto pastoral stations has been minimal although there are serious infestations on a few stations. Total eradication is unrealistic, the main goal is to stop spread away from infested areas. Saffron thistle is therefore in the control and containment category. It is unlikely to become a significant environmental problem or major problem to the pastoral industry. For this reason there is no compulsion to treat it on leasehold land but assistance is available from Agriculture Western Australia if leaseholders choose to undertake control.

Saffron thistle is not widespread but is a serious local problem

Declared animals – native species

Kangaroos

Red kangaroo *(Macropus rufus)*

Euro *(Macropus robustus)*

Western grey kangaroo *(Macropus fuliginosus)*

All three species are found throughout the survey area, with the red kangaroo being more common and widespread than the other two. In 1993 the total red kangaroo population in the Sandstone and half the Mt Magnet management zones, which approximates to the survey area, was estimated to be 92,000 (Southwell 1993). Red kangaroos are most plentiful in areas with good grass and herb cover and where some trees or shrubs are available for shade.

Significance

Kangaroos compete directly with domestic livestock for feed and are sufficiently mobile to respond to local variations in available feed. Station managers generally maintain that kangaroos have most impact on station management and pastoral production during drought and studies (Wilson 1991a,b) confirm this.

Kangaroos can adversely affect the regeneration of shrubs and perennial grasses (Gardiner 1986a,b; Wilson 1991b; Norbury and Norbury 1992, 1993; Norbury *et al.* 1993), a fact which must be recognised when regeneration programs are planned. It is also important to recognise that in many arid rangeland areas, kangaroo numbers increased after European settlement as new watering points were created or habitats altered (Ealey 1967; Oliver 1986).

Status and management

Kangaroos in WA are declared animals in category A7 under the Agriculture & Related Resources Protection Act. All kangaroos are subject to management programs determined by the Kangaroo Management Advisory Committee and administered by the Department of Conservation and Land Management (McNamara and Prince 1986)

They are harvested for pet meat by licensed shooters and harvesting levels are revised in the light of population trends. The aim is to manage the population so that the species is not endangered while at the same time preventing unacceptable damage to the rangelands. Red kangaroo numbers in the survey area in 1993 were at their lowest (92,000) since aerial census commenced in 1984 and well below the peak of about 216,000 in 1987. The major control on populations is seasonal conditions rather than any Government strategy.

Dingo *(Canis familiaris dingo)*

Dingoes are not common. They are found occasionally on pastoral properties and more commonly at the margins of the agricultural areas in particular at the junction of the Number One Vermin Proof Fence and the State Emu Fence.

Significance

The impact of dingoes is low however the potential is significant. Research has shown that when dingoes contact sheep, losses will occur (Thomson 1984).

Status and management

Dingoes are declared animals and the aim of control work is to remove them on or near pastoral country in order to prevent harassment and killing of stock. Most control activities occur on stocked land and the immediate environs. Control on pastoral land is in the form of aerial baiting using 1080 dried meat baits and ground control by a dogger. It is speculated that the effectiveness of 1080 baiting in controlling dingoes has facilitated the explosion in feral goat numbers in this region

Emus *(Dromaius novaehollandiae)*

Emus are widely distributed through the survey area. They occur in higher densities in sheep pastoral areas than in either grain growing or non-pastoral areas (Grice *et al.* 1985). Concentrations occasionally occur after two or more good seasons.

Significance

Emus are not considered to be a major forage competitor with livestock (Davies 1978). They are more of a nuisance, damaging fences and sometimes interfering with sheep mustering and trapping operations.

Status and management

Emus are protected native birds. Their populations are controlled mainly by seasonal conditions and to some extent by predators, including dingoes. They can be controlled by shooting or poisoning when they cause unacceptable damage. Farming of emus has some commercial potential and one farm, on Mt Gibson station, is operating in the survey area.

The Number One Vermin Proof Fence was constructed in the early 1900's to restrict the westward movement of emus into the agricultural areas.

Wedge-tailed eagles *(Aquila audax)*

Wedge-tailed eagles are found throughout the survey area.

Significance

They are capable of catching many different animals. Studies near Carnarvon of the prey taken by eagles to nests showed that young kangaroos made up the largest single component of the diet, with birds, lambs, rabbits, foxes and goats also featuring prominently (Brooker and Ridpath 1980). Eagles do kill lambs, however it is generally considered that the number of lambs consumed as live prey represents a small proportion of total losses.

Status and management

Wedge-tailed eagles are currently declared birds throughout the survey area. This allows numbers to be reduced and restricted, though Agriculture Western Australia makes no recommendations for, nor does it enforce, the control of wedge-tailed eagles. In practice, pastoralists are able to carry out control work on an *ad hoc* basis if they think it necessary and some eagles are killed, particularly at lambing time.

Declared animals – introduced species

Feral goats *(Capra hircus)*

Feral goats occur on every pastoral property in the survey area. In 1993 total population was estimated to be 70,000 (Southwell 1993).

Significance

Overseas studies have shown that overgrazing by goats has seriously altered the balance of species in plant communities as well as drastically reducing the total vegetation present (Hamann 1979). Movements of goats are unchecked by standard sheep fencing, exacerbating the problems of pasture conservation and erosion control. Goats are also seen as a problem species because of their potential to act as a reservoir of infection in the event of the outbreak of exotic disease.

Throughout the area goats make up a substantial part of the total grazing pressure. As such they compete with sheep, each feral goat reducing the sheep carrying capacity of a station by about 0.75 to 1 dry sheep equivalents (dse). They contribute to rangeland degradation in favoured grazing areas and around watering points. Goats also favour habitats such as breakaway plateaux and greenstone hills which locally support endemic and/or rare and endangered plant species.

Status and management

Feral goats are declared animals and the Agriculture Protection Board and local Land Conservation District (LCD) groups have a co-ordinated program aimed at eradication. Control techniques include trapping and mustering for sale, destruction on the property and aerial control using a helicopter as a shooting platform

Goats thrive in many pastoral areas, highlighting their potential for meat and fibre production in these areas. The ability of goats to use and perform well on vegetation types which are poorly suited to sheep production has been demonstrated in Western Australian rangelands (Fletcher 1991). Goat production may be a feasible alternative to sheep production on certain types of country. Controlled grazing systems and improved marketing arrangements would be essential for ecological and economic sustainability.

Wild dogs *(Canis familiaris)*

Quite large populations of domestic dogs exist in the towns and settlements within the survey area.

Significance

The spasmodic depredations of domestic or near feral dogs from towns and settlements are more serious and difficult to control than dingoes. Sheep stations close to settlements sometimes suffer substantial losses.

Status and management

The spasmodic encroachment of domestic dogs onto pastoral properties is difficult to control. The shire councils generally do not have the resources to implement the relevant sections of the Dog Act. Most control work is undertaken by pastoralists and contract doggers by shooting and poisoning.

Foxes *(Vulpus vulpus)*

Foxes are widespread through the survey area.

Significance

Foxes are not considered a major threat to the pastoral industry. Occasional lamb losses have been reported. Studies

show that although foxes do kill some lambs most eaten are either already dead or moribund (Hubach 1981). Foxes pose a threat to native fauna (Kinnear *et al.* 1988) and may have caused the extinction of some species (Christensen 1980). They would become important carriers of rabies if the disease reached Australia.

Status and management

Foxes are a declared animal, although no major co-ordinated control work is carried out. Some spot control occurs on individual stations. Some control also occurs as a result of aerial baiting for dingoes and wild dogs.

Foxes are widespread, they pose more of a threat to native animals than domestic livestock

Rabbits *(Oryctolagus cuniculus)*

The rabbit has not become as abundant in the survey area as along the coast. Small populations exist in restricted favoured habitats such as calcareous plains and sandy banks and kopi dunes near salt lakes where the excavation of warrens is easier.

Significance

Rabbits have only a localised impact. Environmental conditions in the survey area do not generally favour rabbits and they are unlikely to become a serious problem.

Status and management

Isolated fumigation and some poison work is undertaken by pastoralists.

Cats *(Felis catus)*

Cats are common throughout the survey area.

Significance

Feral cats pose no economic threat to the pastoral industry. However, they have adverse effects on populations of native animals (Fitzgerald and Veitch 1985; Burrows and Christensen 1994).

Status and management

No management policies exist for feral cats, which are established throughout pastoral and unoccupied parts of the arid zone. They appear destined to remain an unfortunate component of the Australian fauna. Pastoralists are known to shoot cats in an effort to reduce numbers. Desexing of station cats will minimise the impact of domestic cats turning feral.

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Native fauna

A. Chapman

The fauna records reported in this paper are of mammals, reptiles and frogs derived from the Western Australian Museum fauna database of specimens collected from the Sandstone, Youanmi, Barlee, Ninghan, Kirkalocka, Yalgoo and Perenjori 1:250,000 map sheet areas. In addition some locally extinct mammals indicated by an asterisk in Table 1 are from a surface cave deposit 70 km north of Mt Manning Range (see Table 6 in Burbidge *et al.* 1995). The numbat (*Myrmecobius fasciatus*) record is from Youngson and McKenzie (1977).

Bird data are derived from biological surveys at Karroun Hill nature reserve (Youngson and McKenzie 1977), Mt Elvire state forest (CALM unpublished), Wilroy Nature Reserve (Dell 1979a), Buntine Nature Reserve (Dell 1979b), Burnerbinmah station (CALM unpublished and Storr 1985). Nomenclature follows Christidis and Boles (1994).

Mammals, birds, reptiles and frogs with common names where available are listed in Tables 1-4 respectively. Although these data are derived from numerous sources, they are conservative in that they are names of animals actually recorded from the area; there will be others which occur or occurred here but for which there is no record in the above databases. The bilby (*Macrotis lagotis*) for example almost certainly once occurred in the Sandstone-Yalgoo-Paynes Find area.

Nature of the vertebrate fauna

It is apparent from the data in Table 1 that the Sandstone-Yalgoo-Paynes Find survey area with 37 presently occurring mammal species from nearly all the families of Australian mammals has a very diverse fauna. By comparison 46 presently occurring species are recorded by the WA Museum for the wheatbelt. Additionally Van Vreeswyk (1994) recorded 30 presently occurring species for the rangeland resource survey of the north-eastern Goldfields. Note that prior to European settlement at least an additional 11 mammal species were known from the Sandstone-Yalgoo-Paynes Find area.

Mammal records of particular interest are the long-tailed dunnart (*Sminthopsis longicaudata*) from the Booylgoo Range; the most southerly record for this species in Western Australia which raises the possibility that it may occur elsewhere in the Goldfields. The records of tammar (*Macropus eugenii*) and quokka (*Setonix brachyurus*) were from Winchester in 1929 and Coorow in 1949 respectively; both these sites are outside the south-western extremity of the survey area; here they are beyond the present range of both species; and almost certainly no longer occur here. The record of little red flying fox (*Pteropus scapulatus*) is of interest; it is a vagrant record as this is a northern and eastern species; in WA it occurs as far south as Carnarvon.

The honey possum (*Tarsipes rostratus*) is a south-western species on the edge of its range at the south west of the survey area.

The echidna (Tachyglossus aculeatus) occurs throughout Western Australia including arid and semi-arid country

The number of bird species recorded (Table 2) is 156, this is comparable to 152 recorded by Van Vreeswyk (1994) for the north-eastern Goldfields and exceeds 132 recorded by Kitchener *et al.* (1982) for reserves in the wheatbelt. The avifauna is typically semi-arid with several south-western species including western yellow robin, southern scrub robin, golden whistler, short-billed black cockatoo on the edge of their range at the south-west corner of the survey area. These are species not usually associated with pastoral lands in Western Australia. The families Accipitridae (raptors) and Meliphagidae (honeyeaters) are particularly well represented each with 13 species. With 26 species recorded, waterfowl make a significant contribution to the avian species richness. Significant wetlands include freshwater lignum swamps on Thundelarra station, Lakes Moore, Monger, Mason and Barlee; the latter has been registered in a directory of important Australian wetlands (Australian Nature Conservation Agency undated).

With 109 taxa the reptile richness (Table 3) is comparable to both the wheatbelt which has 117 species (Chapman and Dell 1985) and the north-eastern Goldfields survey area which has 108 (Van Vreeswyk 1994). Particularly well represented are the arid-adapted families Agamidae (dragons) with 17 species, Gekkonidae (gekkoes) with 24. The family Pygopodidae (legless lizards) which has radiated widely on sandplains contributes a south-western component.

Perenties (Varanus giganteus) and other monitors are common active predators and scavengers in the survey area

Table 1. Native mammal species recorded in the survey area
(* indicates recorded in fossil cave deposit - see text)

Family	Species	Common name
Canidae	*Canis familiaris dingo*	dingo
Dasyuridae	*Antechinomys lanige*	kultarr
	* *Dasycercus cristicauda*	mulgara
	Ningaui ride	wongai ningaui
	Ningaui yvonnae	Goldfields ningaui
	* *Phascogale calura*	red-tailed wambenger
	Pseudantechinus woolleyae	Woolley's antechinus
	Sminthopsis crassicaudata	fat-tailed dunnart
	Sminthopsis dolichura	little long-tailed dunnart
	Sminthopsis granulipes	white-tailed dunnart
	Sminthopsis hirtipes	hairy-footed dunnart
	Sminthopsis longicaudata	long-tailed dunnart
	Sminthopsis macroura	stripe-faced dunnart
	Sminthopsis ooldea	Ooldea dunnart
	Sminthopsis youngsoni	
	* *Sminthopsis psammophila*	sandhill dunnart
Macropodidae	*Macropus eugenii*	Tammar wallaby
	Macropus fuliginosus	grey kangaroo
	Macropus robustus	euro
	Macropus rufus	red kangaroo
	Setonix brachyurus	quokka
Myrmecobidae	*Myrmecobius fasciatus*	numbat
Tarsipedidae	*Tarsipes rostratus*	honey possum
Peramelidae	* *Chaeropus ecaudatus*	pig-footed bandicoot
	* *Perameles bouganville*	western barred bandicoot
Molossidae	*Mormopterus planiceps*	little mastiff bat
	Tadarida australis	white-striped mastiff bat
Emballonuridae	*Taphozous hilli*	Hill's sheathtail bat
Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat
	Chalinolobus morio	chocolate wattled bat
	Eptesicus baverstockii	
	Eptesicus finlaysoni	
	Eptesicus regulus	King River eptesicus
	Nyctophilus geoffroyi	lesser long-eared bat
	Nyctophilus major	
	Nyctophilus timoriensis	greater long-eared bat
	Scotorepens balstoni	western broad-nosed bat
	Scotorepens greyii	little broad-nosed bat
Pteropidae	*Pteropus scapulatus*	little red flying-fox
Tachyglossidae	*Tachyglossus aculeatus*	echidna
Muridae	* *Leporillus conditor*	greater stick nest rat
	* *Leporillus apicalis*	lesser stick nest rat
	Notomys alexis	spinifex hopping mouse
	Notomys mitchellii	Mitchell's hopping mouse
	* *Notomys amplus*	short-tailed hopping mouse
	Pseudomys albocinereus	ashy-grey mouse
	Pseudomys bolami	Bolam's mouse
	* *Pseudomys desertor*	desert mouse
	* *Pseudomys fieldii*	Shark Bay mouse
	Pseudomys hermannsburgensis	sandy inland mouse

Table 2. Bird species recorded in the survey area
(I - Increaser species, D - Decreaser species - see text)

Family	Species	Common name
Casuariidae	*Dromaius novaehollandiae*	emu (I)
Podicipedidae	*Poliocephalus poliocephalus*	hoary-headed grebe
Pelicanidae	*Pelecanus conspicillatus*	Australian pelican
Ardeidae	*Ardea pacifica*	white-necked heron
	Egretta novaehollandiae	white-faced heron
Threskiornithidae	*Threskiornis spinicollis*	straw-necked ibis
	Plegadis falcinellus	glossy ibis
Anatidae	*Cygnus atratus*	black swan
	Stictonetta naevosa	freckled duck
	Tadorna tadornoides	Australian shelduck
	Anas superciliosu	Pacific black duck
	Anas gracilis	grey teal
	Malacorhynchus membranaceus	pink-eared duck
	Aythya australis	hardhead
	Chenonetta jubata	Australian wood duck
Accipitridae	*Elanus axillaris*	black-shouldered kite
	Lophoictinia isura	square-tailed kite
	Haliastur sphenurus	whistling kite
	Accipiter fasciatus	brown goshawk
	Accipiter cirrhocephalus	collared sparrowhawk
	Hieraaetus morphnoides	little eagle
	Aquila audax	wedge-tailed eagle (I)
	Circus assimilis	spotted harrier
	Falco subniger	black falcon
	Falco peregrinus	peregrine falcon
	Falco longipennis	Australian hobby
	Falco berigora	brown falcon
	Falco cenchroides	Nankeen kestrel
Megapodiidae	*Leipoa ocellata*	mallee fowl (D)
Phasianidae	*Coturnix pectoralis*	stubble quail
Turnicidae	*Turnix velox*	little button-quail
Rallidae	*Porzana fluminea*	Australian spotted crake (I)
	Gallinula ventralis	black-tailed native hen
	Fulica atra	Eurasian coot
Otididae	*Ardeotis australis*	Australian bustard
Charadriidae	*Vanellus tricolor*	banded lapwing (I)
	Thinornis rubricollis	hooded plover
	Charadrius ruficapillus	red-capped plover
	Elseyornis melanops	black-fronted dotterel
	Erythrogonys cinctus	red-kneed dotterel
	Charadrius australis	inland dotterel (I)
Recurvirostridae	*Cladorhynchus leucocephalus*	banded stilt
	Himantopus himantopus	black-winged stilt
	Recurvirostra novaehollandiae	red-necked avocet
Laridae	*Larus novaehollandiae*	silver gull
	Chlidonias hybridus	whiskered tern
	Sterna nilotica	gull-billed tern
Columbidae	*Columbia livia*	rock dove
	Streptopelia senegalensis	laughing turtle dove (I)
	Geopelia cuneata	diamond dove
	Phaps chalcoptera	common bronzewing (I)
	Ocyphaps lophotes	crested pigeon (I)

Table 2. continued . . .

Family	Species	Common name
Psittacidae	*Polytelis anthopeplus*	regent parrot
	Barnardius zonarius	mulga parrot
	Neophema elegans	elegant parrot
	Neopsephus bourkii	Bourke's parrot (I)
	Melopsittacus undulatus	budgerigah
Cacatuidae	*Nymphicus hollandicus*	cockatiel
	Calyptorynchus banksii	red-tailed black cockatoo
	Calyptorynchus latirostris	short-billed black cockatoo
	Cacatua roseicapilla	galah (I)
	Cacatua leadbeateri	Major Mitchell's cockatoo
Cuculidae	*Cacomantis flabelliformis*	fan-tailed cuckoo
	Cuculus pallidus	pallid cuckoo
	Chrysococcyx osculans	black-eared cuckoo
	Chrysococcyx basalis	Horsefield's bronze cuckoo
	Chrysococcyx lucidus	shining bronze cuckoo
Tytonidae	*Tyto alba*	barn owl
	Tyto novaehollandiae	masked owl
Strigidae	*Ninox novaeseelandiae*	southern boobook
Podargidae	*Podargus strigoides*	tawny frogmouth
Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar
Caprimulgidae	*Eurostopodus argus*	spotted nightjar
Halcyonidae	*Todiramphus pyrrhopygia*	red-backed kingfisher
	Todiramphus sanctus	sacred kingfisher
Meropidae	*Merops ornatus*	rainbow bee-eater
Motacillidae	*Anthus novaeseelandiae*	Richard's pipit (I)
Hirundidae	*Cheramoeca leucosternus*	white backed swallow
	Hirundo neoexna	welcome swallow (I)
	Hirundo nigricans	tree martin
	Hirundo ariel	fairy martin
Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike
	Coracina maxima	ground cuckoo-shrike
	Lalage sueurii	white-winged triller
Petroicidae	*Microeca fascinans*	jacky winter
	Petroica goodenovii	red-capped robin
	Melanodryas cucculata	hooded robin
	Eopsaltria griseogularis	western yellow robin
	Drymodes brunneopygia	southern scrub-robin
Pachycephalidae	*Pachycephala pectoralis*	golden whistler
	Pachycephala rufiventris	rufous whistler
	Pachycephala inornata	Gilbert's whistler
	Colluricincla harmonica	grey shrike-thrush
	Oreoica gutturalis	crested bellbird
Cinclosomatidae	*Psophodes occidentalis*	chiming wedgebill (D)
	Cinclosoma castanotus	chestnut quail-thrush
	Cinclosoma castaneothorax	chestnut-breasted quail-thrush
Dicruridae	*Rhipidura fuliginosa*	grey fantail
	Rhipidura leucophrys	willie wagtail
	Grallina cyanoleuca	magpie-lark (I)
Pomatostomidae	*Pomatostomus superciliosus*	white-browed babbler
	Pomatostomus temporalis	grey-crowned babbler (I)

Table 2. continued . . .

Family	Species	Common name
Pardalotidae	*Pardalotus striatus*	striated pardalote
	Aphelocephala leucopsis	southern whiteface
	Aphelocephala nigricinta	banded whiteface
	Gerygone fusca	western gerygone
	Smicrornis brevirostris	weebill
	Acanthiza apicalis	inland thornbill
	Acanthiza uropygialis	chestnut-rumped thornbill
	Acanthiza robustirostris	slaty-backed thornbill
	Acanthiza iredalei	slender-billed thornbill
	Acanthiza chrysorrhoa	yellow-rumped thornbill (I)
	Pyrrholaemus brunneus	redthroat
	Hylacola cauta	shy heathwren
	Calamanthus campestris	rufous fieldwren (D)
	Amytornis textilis	thick-billed grasswren (D)
Maluridae	*Malurus splendens*	splendid fairy-wren
	Malurus lamberti	variegated fairy -wren
	Malurus pulcherrimus	blue-breasted fairy-wren
	Malurus leucopterus	white-winged fairy-wren (D)
Sylviidae	*Megalurus gramineus*	little grassbird
	Cincloramphus mathewsi	rufous songlark
	Cincloramphus mathewsi	brown songlark
Neosittidae	*Daphoenositta chrysoptera*	varied sitella
Climacteridae	*Climacteris affinis*	white-browed treecreeper
	Climacteris rufa	rufous treecreeper
Dicaeidae	*Dicaeum hirundinaceum*	mistletoe bird
Zosteropidae	*Zosterops lateralis*	silvereye
Meliphagidae	*Lichmera indistincta*	brown honeyeater
	Certhionyx niger	black honeyeater
	Certhionyx variegatus	pied honeyeater
	Lichenostomus virescens	singing honeyeater
	Lichenostomus ornatus	yellow-plumed honeyeater
	Lichenostomus penicillatus	white-plumed honeyeater
	Lichenostomus leucotis	white-eared honeyeater
	Melithreptus brevirostris	brown-headed honeyeater
	Phylidonyris albifrons	white-fronted honeyeater
	Manorina flavigula	yellow-throated miner
	Acanthogenys rufogularis	spiny-cheeked honeyeater
	Anthochaera carunculata	red wattlebird
	Pthianura albifrons	white-fronted chat
	Epthianura aurifrons	orange chat
	Epthianura tricolor	crimson chat
Passeridae	*Taeniopygia guttata*	zebra finch (I)
Artamidae	*Artamus personatus*	masked woodswallow
	Artamus superciliosus	white-browed woodswallow
	Artamus cinereus	black-faced woodswallow
	Artamus minor	little woodswallow
	Cracticus torquatus	grey butcherbird
	Cracticus nigrogularis	pied butcherbird
	Gymnorhina tibicen	Australian magpie
	Strepera versicolor	grey currawong
Corvidae	*Corvus bennetti*	little crow
	Corvus coronoides	Australian raven
Ptilonorhynchidae	*Chlamydera maculata*	spotted bowerbird (I)

Table 3. Reptile species recorded in the survey area

Family	Species	Common name
Agamidae	*Caimanops amphiboluroides*	
	Ctenophorus caudicinctus infans	ring-tailed dragon
	Ctenophorus caudicinctus mensarum	ring-tailed dragon
	Ctenophorus cristatus	crested dragon
	Ctenophorus fordi	
	Ctenophorus inermis	
	Ctenophorus isolepis gularis	military dragon
	Ctenophorus maculatus dualis	
	Ctenophorus ornatus	ornate dragon
	Ctenophorus reticulatus	reticulated dragon
	Ctenophorus salinarum	salt-lake dragon
	Ctenophorus scutulatus	
	Moloch horridus	thorny devil
	Pogona minor minor	bearded dragon
	Typanocryptis cephala	
Boidae	*Aspidites ramsayi*	woma
	Liasis stimsoni	Stimson's python
	Morelia spilota imbricata	carpet python
Cheluidae	*Chelodina steindachneri*	dinner plate tortoise
Elapidae	*Acanthopis pyrrhus*	death adder
	Demansia psammophis reticulata	yellow-faced whipsnake
	Demansia reticulata cupreiceps	spinifex snake
	Demansia psammophis psammophis	
	Denisonia fasciata	Rosen's snake
	Furina ornata	moon snake
	Pseudechis australis	mulga or king brown snake
	Pseudechis butleri	yellow-bellied black snake
	Pseudonaja modesta	five-ringed snake
	Pseudonaja nuchalis	gwardar
	Rhinoplocephalus gouldii	Gould's snake
	Rhinoplocephalus monachus	monk snake
	Vermicella approximans	bandy bandy
	Vermicella bertholdi	bandy bandy
	Vermicella bimaculata	bandy bandy
	Vermicella fasciolata fasciolata	bandy bandy
	Vermicella semifasciata	bandy bandy
Gekkonidae	*Crenadactylus ocellatus*	clawless gekko
	Diplodactylus alboguttatus	
	Diplodactylus assimilis	soft-spined gekko
	Diplodactylus elderi	
	Diplodactylus granariensis granariensis	
	Diplodactylus granariensis rex	
	Diplodactylus maini	
	Diplodactylus michaelseni	
	Diplodactylus ornatus	
	Diplodactylus pulcher	
	Diplodactylus spinigerus	
	Diplodactylus squarrosus	
	Diplodactylus strophurus	
	Diplodactylus wellingtoniae	
	Gehyra punctata	
	Gehyra purpurascens	
	Gehyra variegata	
	Heteronotia binoei	Binoe's gekko
	Nephurus vertebralis	
	Nephurus wheeleri wheeleri	
	Oedura marmorata	marbled gekko
	Oedura reticulata	
	Rhynchoedura ornata	beaked gekko
	Underwoodisaurus milii	barking gekko

Table 3. continued . . .

Family	Species	Common name
Pygopodidae	*Delma butleri*	
	Delma fraseri	
	Delma grayii	
	Delma tincta	
	Lialis burtonis	Burton's legless lizard
	Pygopus lepidopodus lepidopodus	scale-foot
	Pygopus nigriceps nigriceps	
Scincidae	*Cryptoblepharus carnabyi*	
	Cryptoblepharus plagiocephalus	
	Ctenotus atlas	
	Ctenotus helenae	
	Ctenotus leonhardii	
	Ctenotus mimetes	
	Ctenotus pantherinus ocellifer	
	Ctenotus quattordecimlineatus	
	Ctenotus schomburgkii	
	Ctenotus severus	
	Ctenotus uber uber	
	Ctenotus xenopleura	
	Cyclodomorphus branchialis	
	Egernia depressa	
	Egernia formosa	
	Egernia inornata	
	Egernia stokesii badia	
	Eremiascincus richardsonii	
	Hemiergis initialis	
	Lerista gerrardii	
	Lerista macropisthopus macropisthopus	
	Lerista muelleri	
	Menetia greyii	
	Morethia butleri	
	Morethia obscura	
	Sphenomorphus fasciolatus	
	Tiliqua occipitalis	
	Tiliqua rugosa rugosa	
Typhlopidae	*Ramphotyphlops bituberculatus*	
	Ramphotyphlops hamatus	
	Ramphotyphlops waitii	
Varanidae	*Varanus caudolineatus*	
	Varanus eremius	
	Varanus giganteus	perentie
	Varanus gouldii	Gould's monitor
	Varanus panoptes rubidus	
	Varanus tristis tristis	tree goanna

Table 4. Frog species recorded in the survey area

Family	Species	Common name
Hylidae	*Cyclorana maini*	Main's frog
	Cyclorana platycephala	water holding frog
	Litoria moorei	green and golden bell frog
	Litoria rubella	desert tree frog
Leptodactylidae	*Heleioporus albopuctatus*	spotted burrowing frog
	Heleioporus eyrei	moaning frog
	Heleioporus psammophilus	
	Limnodynastes dorsalis	banjo frog
	Neobatrachus centralis	
	Neobatrachus kunapalari	Kunapalari frog
	Neobatrachus pelobatoides	humming frog
	Neobatrachus sutor	shoemaker frog
	Neobatrachus wilsmorei	Goldfields bullfrog
	Pseudophryne occidentalis	western toadlet
	Pseudophryne guentheri	Guenther's toadlet

Frogs too are very well represented with 15 species (Table 4) compared with 17 for the wheatbelt (Chapman and Dell 1985). The fauna comprises a blend of south-western and arid-adapted species.

Examination of the vertebrate fauna reveals that it is predominantly arid-adapted and has a small but distinct semi-arid south-western component. Most of the Perenjori and part of the Yalgoo 1:250,000 map sheets fall within the South West Botanical Province as defined by Beard (1980). There is usually enhanced species richness along biological divides and this accounts in part for the very high numbers of vertebrate species recorded. This is exemplified best by the bird and amphibian fauna. Particular environmental factors influencing the distinctness of the south-western flora and fauna are higher and more reliably seasonal rainfall, denser vegetation with more plant species per unit area, and the tighter mosaic in which landforms, soil types and vegetation formations interact with each other. These factors contribute to greater biodiversity, higher endemism and most species having smaller ranges than in more arid areas.

While any regional or sub-regional fauna can be interpreted in terms of its proximity to adjacent areas, situated where it is, this influence is particularly strong for the fauna of the Sandstone-Yalgoo-Paynes Find survey area. However in recognising the distinctness of the south-west component there is always a danger that the pastoral areas will be assumed to be relatively homogeneous and that their inherent values will be understated. This is certainly not the case here, this pastoral region has very high potential biodiversity occasioned by the presence of both the Austin and Coolgardie botanical districts of Beard (1980) hence both mulga and eucalypt woodlands as well as distinctive landforms such as granite outcrops, lake frontage, greenstone and banded ironstone ranges, breakaways and sandplains. Additionally 8 of the 19 inland wetland types recorded for Australia occur within the survey area.

Changes to the vertebrate fauna

As has happened elsewhere in Australia, particularly in the arid zone, the data for the survey area indicate changes to the fauna since European settlement. These changes are most pronounced for mammals; data in Table 1 and text indicate 11 species which have become locally extinct since settlement. Of these, only the pig-footed bandicoot, and lesser stick-nest rat are presumed extinct throughout Australia, the others survive as threatened species in isolated populations elsewhere. Reasons for these changes have been the subject of both discussion and research e.g. Burbidge and McKenzie (1989) and Morton and Baynes (1985). Medium sized mammals i.e. those weighing between 35 grams and 5.5 kilograms are particularly vulnerable. The factors identified as contributing to this decline are: changes to fire regimes occasioned by the decline in traditional Aboriginal burning practices; increased predation by introduced predators and increased competition or habitat change by introduced herbivores. There is debate as to whether predation or habitat change is the primary factor.

Other native mammals, particularly the large kangaroos, have increased in numbers since settlement due to provision of water supplies and successful dingo control on pastoral lands.

The avifauna of arid pastoral lands has changed with settlement; Curry and Hacker (1990) list 11 species which have declined and 20 which have increased under pastoral management in Western Australia. Increasers and decreasers in the survey area are indicated in Table 2. While there are more increaser than decreaser species, which may be interpreted as a net gain, the decreasers are now, with few exceptions, the threatened species characterised by either declining numbers and/or fragmented populations. Increasers on the other hand are usually species which were common, or at least not rare, elsewhere which are now common in the survey area.

Additionally the nature of the database makes it unlikely that some decreasers will be recorded. In their study of the impact of pastoralism on the Murchison catchment, Saunders and Curry (1990) similarly recognised bird species which had increased and decreased. They also identified 89 species for which there were no indications of change since 1910. This differs from the western division of New South Wales, also occupied by arid pastoralism, where Smith *et al.* (1994) recorded a much higher rate of decline which has not yet

stabilised. Similarly Reid and Fleming (1992) indicated that one half of the arid zone avifauna had changed since European settlement and warned that without widespread regeneration, future extended drought could 'accelerate declines and extinctions'.

Reptiles as a group are more resilient to environmental change than other vertebrates; e.g. Kitchener *et al.* (1980) were unable to demonstrate any loss of species in spite of massive clearing in the wheatbelt. Reasons for reptile resilience are: many species can survive as small isolated populations; their ectothermy enables them to survive food shortage; and they can survive the effects of wild fire due to the above circumstance as well as their use of non-flammable refugia (Chapman and Newbey 1994). Except for pythons (see below) it is unlikely that there has been any change to the diverse reptile fauna of the survey area.

Rare fauna

Of presently occurring mammals, the long-tailed dunnart (*Sminthopsis longicaudata*) is on the Department of Conservation and Land Management's 'reserve' list of threatened fauna. However, 12 gazetted mammal species are now locally extinct in the survey area.

The following birds are gazetted threatened fauna: freckled duck, night parrot, peregrine falcon, mallee fowl, short-billed black cockatoo and Major Mitchell's cockatoo. Of these, mallee fowl conservation and management is the highest priority and greatest challenge. Night parrot was first recorded for WA in 1854 from a site just north of the survey area, about 13 km south-east of Mt Farmer near the western end of Lake Austin. It has not been recorded in WA since 1912; but is now subject to a search project involving extensive pastoralist participation. Hooded plover and spotted nightjar are on the 'reserve' list of threatened fauna.

As indicated reptiles are the least affected vertebrate group; however two pythons, woma (*Aspidites ramsayi*) and carpet python (*Morelia spilota imbricata*), are gazetted threatened. Pythons as a group are vulnerable due to land clearing, loss of suitable habitat (particularly old trees), predation and illegal collecting.

Mallee fowl nest in country that has been recently burnt

Conservation and management of vertebrate fauna

The only lands dedicated to and managed primarily for conservation purposes are Mt Elvire state forest and Burnerbinmah pastoral lease. In addition the northern portion of Karroun Hill and Mt Manning nature reserves extend into the southern edge of the survey area.

Taken together these lands managed primarily for conservation occupy 445, 600 ha or 4.7% of the survey area; ideally 10% should be dedicated to conservation management. Note that it was only possible to achieve even just under 5% by purchase by CALM of two pastoral leases. Prior to this purchase only 1% of the Austin botanical district was managed for conservation purposes (CALM 1992). This is indicative of the requirement that conservation values of pastoral lands are evaluated, recognised by pastoralists, government and the wider community and managed. Pringle (1995) suggests that to succeed, nature conservation in pastoral lands must involve more than just government funded acquisition and management of dedicated reserves. This approach recognises a) that political and economic constraints will mean that representativeness of reserves will never be achieved in arid pastoral lands and b) that most ecological processes cross boundaries and require management across different land tenures. Likewise Curry and Hacker (1990) indicated that under conservative stocking regimes conservation objectives could be met under grazing management in arid WA.

As a pastoral area with very high vertebrate species richness and with the data available from the rangeland survey the Sandstone-Yalgoo area presents an ideal opportunity for an integrated approach to management of rangeland resources.

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The Survey

Methodology (A.M.E. Van Vreeswyk[1])

Geomorphology (A.L. Payne[1] and H.J.R. Pringle[1])

Soils (P. Hennig[1])

Vegetation (H.J.R. Pringle[1])

Ecological assessment (H.J.R. Pringle[1])

Land systems (A.L. Payne[1], A.M.E. Van Vreeswyk[1], H.J.R. Pringle[1] and K.A. Leighton[2])

Resource condition (A.M.E. Van Vreeswyk[1])

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Methodology

A.M.E. Van Vreeswyk

The rangeland resource survey of the Sandstone-Yalgoo-Paynes Find area was jointly undertaken by Agriculture Western Australia (AWA) and the Department of Land Administration (DOLA). Rangeland surveys in Western Australia have been conducted since the 1950s when they were commenced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In 1969 the Pastoral Appraisement Board (now Pastoral Board) commissioned the first regional survey (Wilcox and McKinnon 1972) to be conducted jointly by the Department of Lands and Surveys (now DOLA) and the Western Australian Department of Agriculture (now AWA). Since then a further seven surveys have been completed (Payne *et al.* 1979, Mitchell *et al.* 1979, Payne *et al.* 1982, Payne *et al.* 1987, Payne and Tille 1992, Curry *et al.* 1994 and Pringle *et al.* 1994). The regional survey described here is the ninth in the rangelands of Western Australia.

The land system approach to mapping different country types has been used in all of the previous regional rangeland surveys in WA. Land systems were first used by Christian and Stewart in 1953. They define a land system as an “area with a recurring pattern of topography, soils and vegetation”. These recurring patterns can be seen using aerial photography or other remotely sensed images. Once identified the assumption is made that similar land systems (patterns) represent similar types of country (landscapes). The land systems are then ground-truthed during field work.

Land system boundaries mapped from 1:50,000 scale aerial photographs can be reproduced onto topographical maps or pastoral plans at any required scale. For pastoral management, 1:100,000 scale has been found to be useful both for whole station and paddock uses (Curry *et al.* 1994); 1:50,000 scale plans are better suited for preparation of environmental reviews for engineering and mining projects (e.g. Pringle 1995). The land systems can also be clearly mapped at 1:250,000 or 1:500,000 scale for regional uses.

The minimum sized piece of land which can be mapped at 1:100,000 scale is approximately one square kilometre in extent. Narrower pieces e.g. 500 m wide can be mapped provided they are at least 1.5 km long. This allows linear features such as ranges and long, narrow pieces of severely degraded and eroded land to be mapped.

Reconnaissance field work

Most members of the rangeland survey team had worked in one or more of the adjoining survey areas, and were familiar with survey techniques and the types of country encountered. This made the preliminary work much simpler than on previous surveys.

Aerial photographs covering the survey area at a scale of 1:50,000 were obtained by DOLA. Six of the seven 1:250,000 map sheets were flown especially for the project by DOLA’s aerial photography section in 1991. Existing photography taken in 1980 was used for the Ninghan 1:250,000 map sheet. The photos were black and white with a matt finish.

Topographic features and infrastructure such as roads, fences and watering points, were identified and marked on the aerial photographs. Many sources of information on the biophysical resources of the survey area were reviewed, including Beard’s vegetation survey of the Murchison (1976), the 1:250,000 geological map series produced by Geological Survey of Western Australia, for the sheets covered by the survey area (Baxter *et al.* 1983, Baxter and Lipple 1985, Lipple *et al.* 1983, Muhling and Low 1977, Stewart *et al.* 1983, Tingey 1985, Walker and Blight 1983), the Atlas of Australian Soils (Northcote *et al.* 1968), the Biological survey of the Eastern Goldfields of Western Australia series (e.g. Dell *et al.* 1992, Burbidge et al. 1995) and much unpublished data held by DOLA and AWA.

Members of the survey team mapped provisional land system boundaries onto the aerial photos, using stereoscopes. About three-quarters of the land systems used in the survey had previously been described in the Wiluna-Meekatharra area (Mabbutt *et al.* 1963), Murchison (Curry *et al.* 1994) and/or the north-eastern Goldfields (Pringle *et al.* 1994).

Some country types, particularly in the south-west, were different to that previously mapped in other survey areas. It was decided to sample these areas more intensively during the reconnaissance field work.

After the initial photo interpretation the photos were laid out and traverse routes were planned for the reconnaissance trips. In 1992 the survey team undertook three trips, which lasted two weeks each. The first in September covered the Sandstone, Youanmi and part of the Barlee map sheets; the second in October-November covered the Yalgoo and Kirkalocka map sheets; and the final trip in November-December covered the Perenjori, Ninghan and the remainder of the Barlee map sheet. Because of the large area to be covered in a relatively short space of time, the route mainly stayed on roads and major tracks, and the team moved through quickly, camping in a different place each night. As well as sampling new land systems, the work concentrated on developing techniques for the main field work.

Detailed descriptions of the soil and vegetation were made at 128 inventory sites during the reconnaissance trips. One quarter of these were on previously undescribed land systems.

An assessor recorded the land system, land unit and habitat at kilometre intervals along the traverse. This allowed descriptions of land systems to be built up, including the proportion of each land unit within a land system, and the variation of habitats within each land unit. Severely degraded and eroded areas of at least 40 ha in extent, were mapped onto the aerial photographs and the location of country in ‘near pristine’ condition (potential ‘reference’ areas) was recorded.

Plant species which could not be identified were collected and their locations recorded. The specimens were identified by staff at the Conservation and Land Management herbarium and a field herbarium of identified specimens was prepared. This field herbarium was updated throughout the survey. A list of all perennial species recorded in the survey area, and their collection numbers, can be found in Appendix 1.

After the reconnaissance trips, during the summer of 1992-93 the survey team had opportunity to refine the methodology and prepare tentative land system and habitat descriptions, and to fully plan the main trips.

Main field work

Between May and November 1993 seven trips lasting three weeks each were made to the survey area. Two survey teams worked alternately in the field. Each team comprised two rangeland advisers and a soils technician from Agriculture Western Australia, and a surveyor and navigator from DOLA. The teams were supported by a survey hand from DOLA. The staff involved in the fieldwork were:

Rangeland advisers	A.L. Payne, A.M.E. Van Vreeswyk, H.J.R. Pringle, D.A. Blood
Staff surveyors	K.A. Leighton, S.A. Gilligan
Navigators	J. Holmes, P.T. Godden
Soil technicians	P. Hennig, M. Newell
Senior survey hand	L.J. Merritt

One team covered the Yalgoo, Kirkalocka, Perenjori and Ninghan map sheets, while the other worked on the Sandstone, Youanmi and Barlee map sheets.

The area was surveyed on a station-by-station basis. Prior to each trip traverse routes were planned for the pastoral leases to be visited. Inventory and condition sites were pre-selected along the traverse routes.

The teams generally stayed at shearers' quarters on a station for half of the three-week trip, then moved to another station for the second part. While at shearers' quarters the team would cover the home station and two or three adjoining stations. Between one and three days was spent on each station, depending on size. Pastoralists were notified when the team would be in their area and encouraged to spend at least one day with the team while it was surveying their station.

During field work the surveyor and navigator checked and updated the position of infrastructure which had been transposed onto the aerial photos from existing 1:100,000 scale topographic maps, station plans and geological maps. Names of wells and bores were checked with the pastoralist, and new watering points, tracks and fences were plotted on the 1:100,000 topographic maps and their geographical position stored using a Global Positioning System (GPS) navigation unit. This ensured that the land resource information could be provided on an accurate base map.

Traverses

The navigator followed the predetermined traverse on the aerial photos, and in this way the land system boundaries could be verified and amended where necessary by the assessor. In addition to recording the land system, land unit and habitat at kilometre intervals along the traverse, as was done on the reconnaissance trips, an assessment of range condition at each of these points was made. The range condition was recorded as a rating of the vegetation condition (see Table 1) and the extent and type of accelerated erosion (see Table 2) at the site. The 'site' is considered to be an area within a 50 m radius of the vehicle at the kilometre interval point.

The vegetation condition ratings are subjective visual assessments. They are based on the assessor knowing what type of vegetation is supported on the particular landform/soil association being assessed, and having an understanding of the 'natural' range in such attributes as species composition, density and cover, and likely changes in these attributes that occur as a result of (unnatural) disturbance. If the site is judged to be in the 'natural' range it is rated as being in very good condition. If there have been induced changes in the 'natural' range, the site is rated as good, fair, poor or very poor, depending on the extent of the changes. Pastoralism is by far the most extensive land use in the survey area, and the changes seen are mostly due to the impact of grazing animals, including introduced stock, feral animals and native herbivores. However, changes due to other causes such as fire, mining, tourism and infrastructure are also commonly encountered.

Table 1. Criteria for assessment of vegetation condition

Rating	Condition indicators
1	Excellent or very good For the land unit-vegetation type (habitat), the site's cover and composition of shrubs, perennial herbs and grasses is near optimal, free of obvious reductions in palatable species or increases in unpalatable species, or the habitat type supports vegetation which is predominantly unattractive to herbivores and is thus largely unaltered by grazing.
2	Good Perennials present include all or most of the palatable species expected; some less palatable or unpalatable species may have increased, but total perennial cover is not very different from the optimal.
3	Fair Moderate losses of palatable perennials and/or increases in unpalatable shrubs or grasses, but most palatable species and stability desirables still present; foliar cover is less than on comparable sites rated 1 or 2 unless unpalatable species have increased.
4	Poor Conspicuous losses of palatable perennials; foliar cover is either decreased through a general loss of perennials or is increased by invasion of unpalatable species.
5	Very poor Few palatable perennials remain; cover is either greatly reduced, with much bare ground arising from loss of stability desirables, or has become dominated by a proliferation of unpalatable species.

Table 2. Criteria for assessment of accelerated erosion

1. Quantitative measure of area affected by erosion

Rating	Severity
0	No accelerated erosion present
1	Slight erosion (<10% of site affected)
2	Minor erosion (10-25% of site affected)
3	Moderate erosion (25-50% of site affected)
4	Severe erosion (50-75% of site affected)
5	Extreme erosion (75-100% of site affected)

2. Type of erosion present (dominant type recorded)

Rating	Erosion characteristics present
0	No erosion
A	Microterracing/sheeting
B	Scalding/capping
C	Pedestalling
D	Rilling/guttering
E	Guttering/gullying
F	Accelerated accretion of soil material

Evidence of fire was recorded at each traverse assessment point, and the type of evidence was noted: patterns on the aerial photograph, the structure of the vegetation e.g. majority of the vegetation of a uniform age, presence of a large number of colonisers or opportunistic species, burnt stumps and bases of trees and/or the presence of charcoal or other burnt objects on the soil surface.

If an assessment point occurred on an area undergoing mining or exploration activities, this was recorded, but the site was not assessed for range condition. If an assessment point fell within 100 m of a watering point, or on a major road or within homestead or shearing shed grounds the point was not assessed for range condition.

Areas which had been interpreted as being severely degraded and eroded on the aerial photographs were visited to verify that they were degraded, and to ensure that their extent was accurately mapped.

One hundred and thirty-six traverse routes, each generally between 50 and 160 km long, were completed in the survey area. These are shown in Figure 1. Some 9,790 traverse points were recorded in the survey area, 9,435 of these have a range condition assessment. The geographical location of the traverse points were stored using a GPS navigation unit.

Inventory sites

Inventory sites were pre-selected during traverse planning. They were selected to ensure that each major land unit within each land system was adequately sampled and could be described, and to help with interpreting the aerial photo patterns. Occasionally, when a different land unit/vegetation/soil association was encountered, additional sites were selected in the field.

The inventory sites are directed at collecting information at a land unit scale. The 'site' is considered to be an area within a 50 m radius of the vehicle. If the unit is smaller, the assessor would only record information for the area within the selected unit.

At inventory sites detailed information on the landform, vegetation and soil was recorded. The attributes were recorded in code form on a standard record sheet based on those used by Curry *et al.* (1994) in the Murchison regional survey. The attributes recorded at inventory sites were:

General
- site number
- land system
- land unit
- pastoral station
- 1:250,000 map sheet name
- aerial photograph year, run and number
- date
- compass bearing of the site photograph

Physical environment
- slope (in percentage)
- unit relief
- geology (according to 1:250,000 Geological Survey series)
- site geology – if different to the mapped geology
- surface mantle abundance, shape, size and type
- outcrop abundance and type
- type and intensity of accelerated erosion features (Table 3)
- vegetation condition rating (Table 1)
- extent and type of surface crusting
- evidence of fire

Vegetation
- habitat
- projected foliar cover (PFC) class of perennial shrubs (Curry *et al.* 1983)
- the dominant species in each stratum
- the relative dominance of each stratum
- basal cover class for perennial grasses
- height class of tree stratum
- height class of tall shrub stratum
- list of perennial plant species

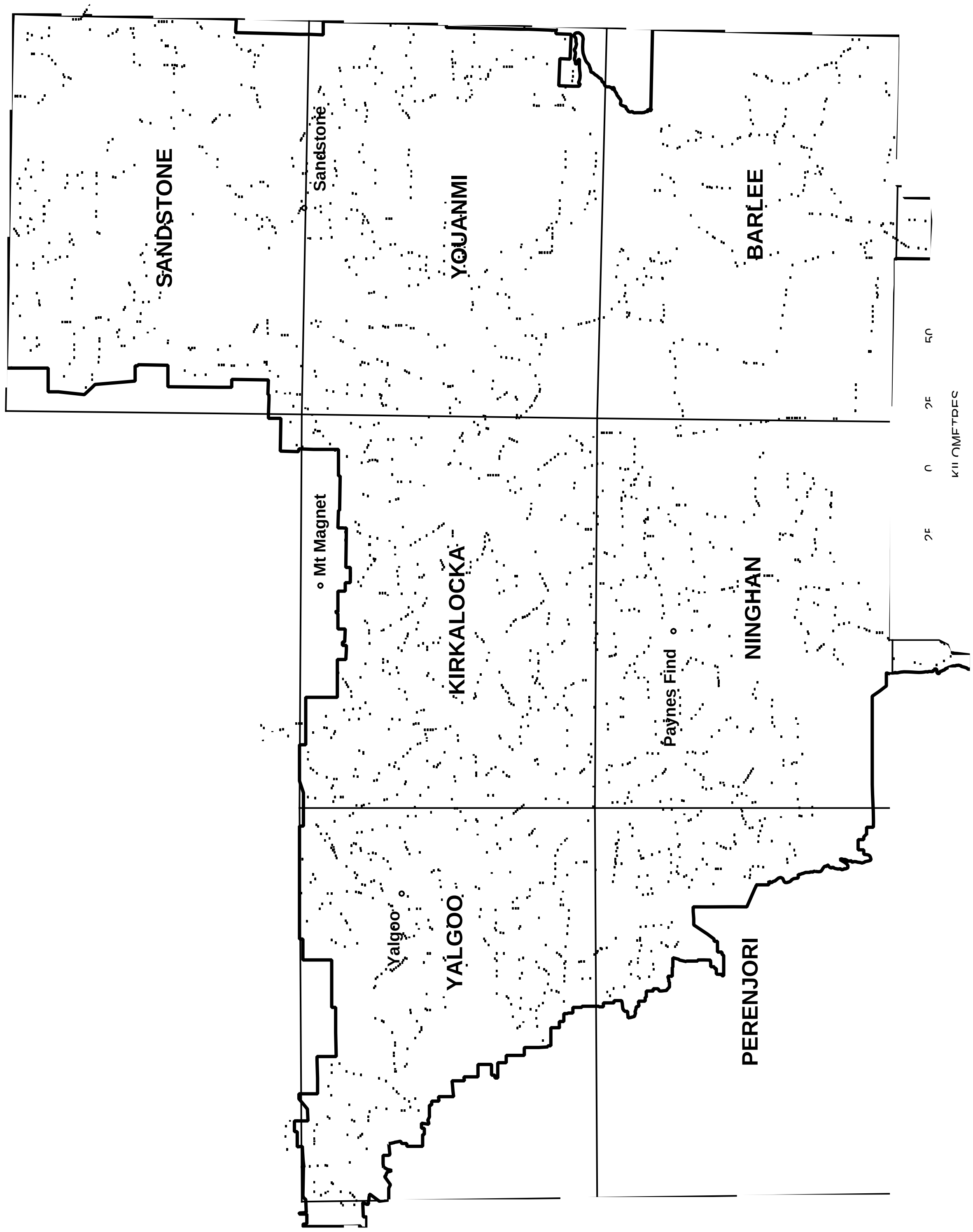

Figure 1. Traverse routes in the survey area

Soil
- Principal profile form (Northcote 1979)
- total soil depth
- substrate
- soil surface condition
- type and structure of pans
- soil reaction trend
- observation method
- details of each soil horizon; horizon designation, depth, texture and texture group, moist colour, soil moisture status, consistence, porosity, fabric, structure, ped shape, boundary distinctness, abundance, shape, size and type of coarse fragments and segregations, effervescence with concentrated hydrochloric acid, and field pH.

Notes and landscape sketches were also made on an *ad hoc* basis. At each site a standardised method was used to take photographs (slide and colour print) from the roof of the survey vehicle, with a board identifying the survey area and the site number placed approximately 10 m from the vehicle.

Describing a soil profile among seasonal wildflowers at an inventory site

Table 3. Criteria for assessment of accelerated erosion at sites

Type - intensity combination	Rating
No accelerated erosion present	00
Slight erosion (<10% of site affected)	
Slight accumulation of wind-blown soil around plant bases and other obstacles and/or	11
Removal of finer soil particles evident but soil crust is largely intact and/or	12
Occasional rills (<300 mm deep evident) and/or|	13
A few scalds present, usually <2 m in diameter	14
Minor erosion (10-25% of site affected)	
Accumulation of soil around plant bases with plant mounds noticeable enlarged and/or	21
Evidence of pedestalling but soil loss minor and plant bases not greatly elevated and/or	22
Breaking of surface crust with small erosion faces and some redistribution of soil and/or	23
Rilling evident but no gully development and/or	24
Scalding evident but scalds relatively small and discontinuous	25
Moderate erosion (25-50% of site affected)	
Wind piling around plant bases and other obstacles is common but no plants completely covered and/or	31
Pedestalling apparent with plant bases distinctly raised and with obvious soil loss and/or	32
Rilling common or gullying present on parts of site, and/or	33
Surface sheeting with erosion faces (and/or microterracing) and active redistribution of soil and/or	34
Wind scalds common	35
Severe erosion (50-75% of site affected)	
Extreme hummocking around plants and other obstacles; some plants completely covered and/or	41
Severe pedestalling with plant bases greatly elevated and major soil loss and/or	42
Widespread rilling or major gullying and/or	43
Scalding extensive, smaller scalds have coalesced to form large, more or less continuous scalded areas and/or	
Surface sheeting with extensive exposure of subsoil or parent material ; erosion faces (and/or	44
microterracing) and active redistribution of soil, and/or	45
Much of surface generally unstable with ripple mark formation	46
Extreme erosion (75-100% of site affected)	
General surface movement, total surface area bare with formation of shifting dunes and/or	51
Surface sheeting and/or scalding complete with exposure of subsoil or parent material and/or	52
Extensive gullying	53

The assessors generally spent between 30 and 60 minutes at a site to complete this description. The geographical location of each site was stored on a GPS so it could be mapped at a later date.

During the fieldwork 846 inventory sites were sampled. Figure 2 shows their location throughout the survey area.

Condition sites

Condition site sampling was first implemented in the rangeland survey of the Murchison River catchment (Curry *et al.* 1994). It was designed as a quantitative approach to investigating various site attributes which could be used as key variables of grazing impact and to characterise the full pattern of condition states within major habitats. It also enables the most powerful indicators of soil and vegetation status to be determined. These indicators would be of value in one-off assessments, such as for land and conservation status, and in evaluating ecosystem change (e.g. at WARMS sites). The indicators also provide a means of quantitatively calibrating visual (qualitative) resource condition assessments.

This type of sampling and analysis has been done previously for 14 habitats in the Murchison (Curry *et al.* 1994) and 10 in the north-eastern Goldfields (Pringle *et al.* 1994). The survey team undertook intensive condition sampling on four important habitats which would be encountered during the survey. The habitats were selected because they were extensive but had not been sampled during previous surveys, or were new to this survey area. The habitats were:

- sandy granitic acacia shrubland (SGRS)
- breakaway footslope chenopod low shrubland (BCLS)
- hardpan plain mulga and bowgada shrubland or woodland (MUBW)
- stony plain bluebush mixed shrubland (SBMS)

The following attributes were recorded in code form at each site on a standard record sheet based on those used by Curry *et al.* (1994) in the Murchison survey.:

General
- site number
- land system
- land unit
- pastoral station
- traverse number
- site technique(s)
- 1:250,000 map sheet name
- aerial photograph year, run and number
- date
- paddock and quadrant
- habitat
- area sampled
- name of the nearest watering point
- distance from the nearest watering point
- salinity of the nearest watering point

Physical environment
- type and intensity of accelerated erosion
- vegetation condition
- extent and type of surface crusting
- evidence of fire
- slope (in percentage)
- surface mantle abundance, shape, size and type

Vegetation
- projected foliar cover class of perennial shrubs
- the dominant species in each stratum
- the relative dominance of each stratum
- basal cover class for perennial grasses
- density or rank of each perennial plant species
- indicator value of each species (Table 4)
- level of recent grazing of each species
- level of historic grazing of each species
- population structure of each species

Table 4. Species indicator values

Decreaser
Highly palatable species whose cover and density decline under excessive grazing pressure.

No indicator value
Species which are generally not grazed and hence not affected by grazing pressure except in extreme situations.

Intermediate
Moderately palatable species which, under grazing, initially increase relative to desirable species or increase in absolute terms as they utilise niches vacated by (more palatable) decreasers. Intermediate species may dominate the stand. They decline under extreme grazing pressure, and are common in areas regenerating from severe degradation.

Increaser
Generally unpalatable species which increase in number and cover as decreaser species decline under excessive grazing. Also common in disturbed (e.g. fire) areas.

Two sampling techniques were used to provide a density of each perennial plant species, depending on the type of vegetation being sampled. At sclerophyllous shrubland sites (MUBW and SGRS), perennial shrub species were counted within a measured area (usually two 500 m^2 quadrats). For halophytic communities (SBMS and BCLS) the perennial shrub species were counted within a smaller area (usually two 200 m^2 quadrats, each 100 m long by 2 m wide).

Condition site sampling in a saltbush community

Notes and landscape sketches were made on an *ad hoc* basis and colour print and slide photographs were taken at each site using the standardised method used at inventory sites. The assessors generally spent between 40 and 60 minutes at each of the 144 sites to complete this description and measurement. The geographical location of each site was stored on a GPS navigation unit so it could be mapped at a later date. Figure 3 shows their location throughout the survey area.

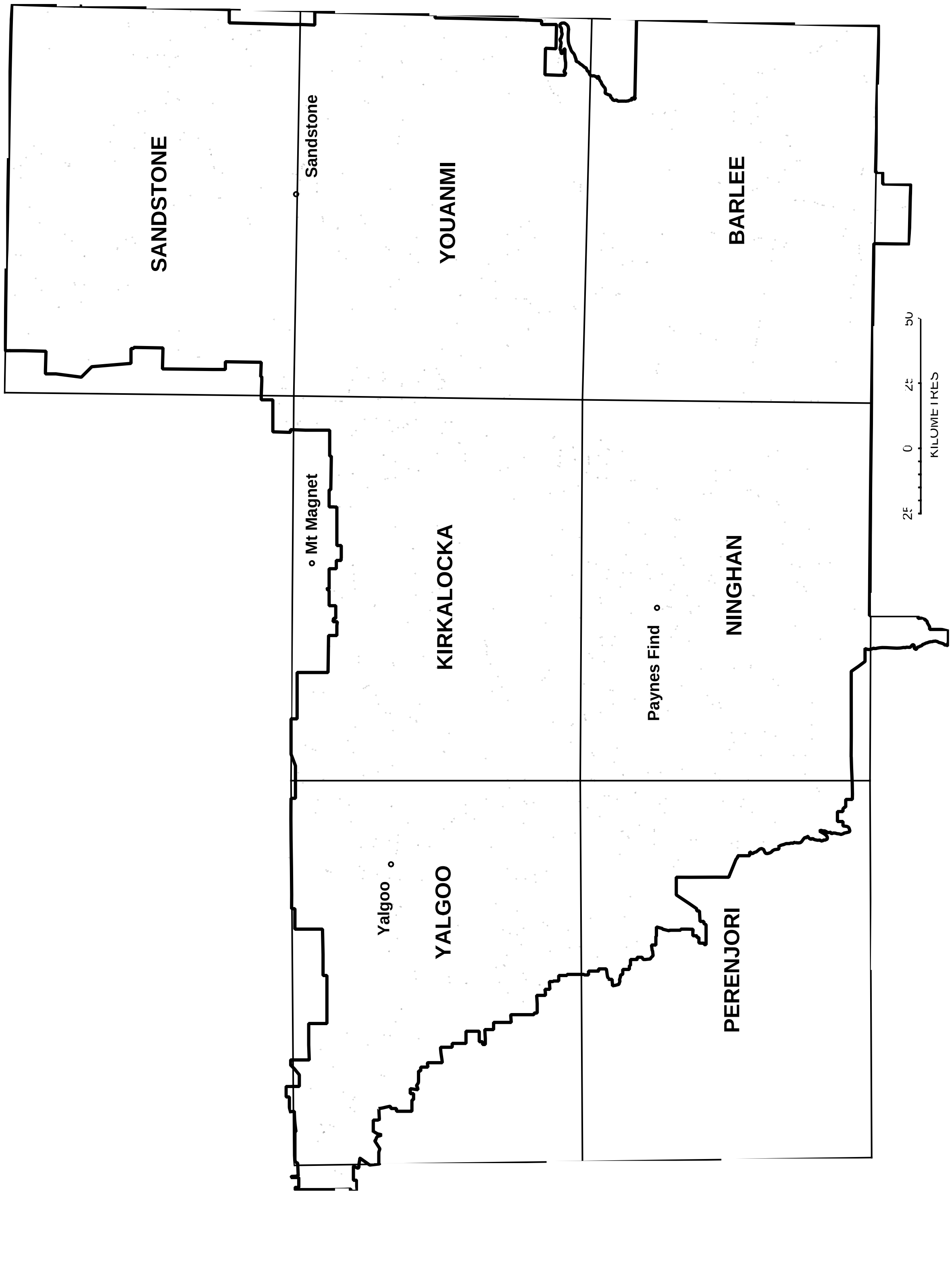

Figure 2. The distribution of inventory sites in the survey area

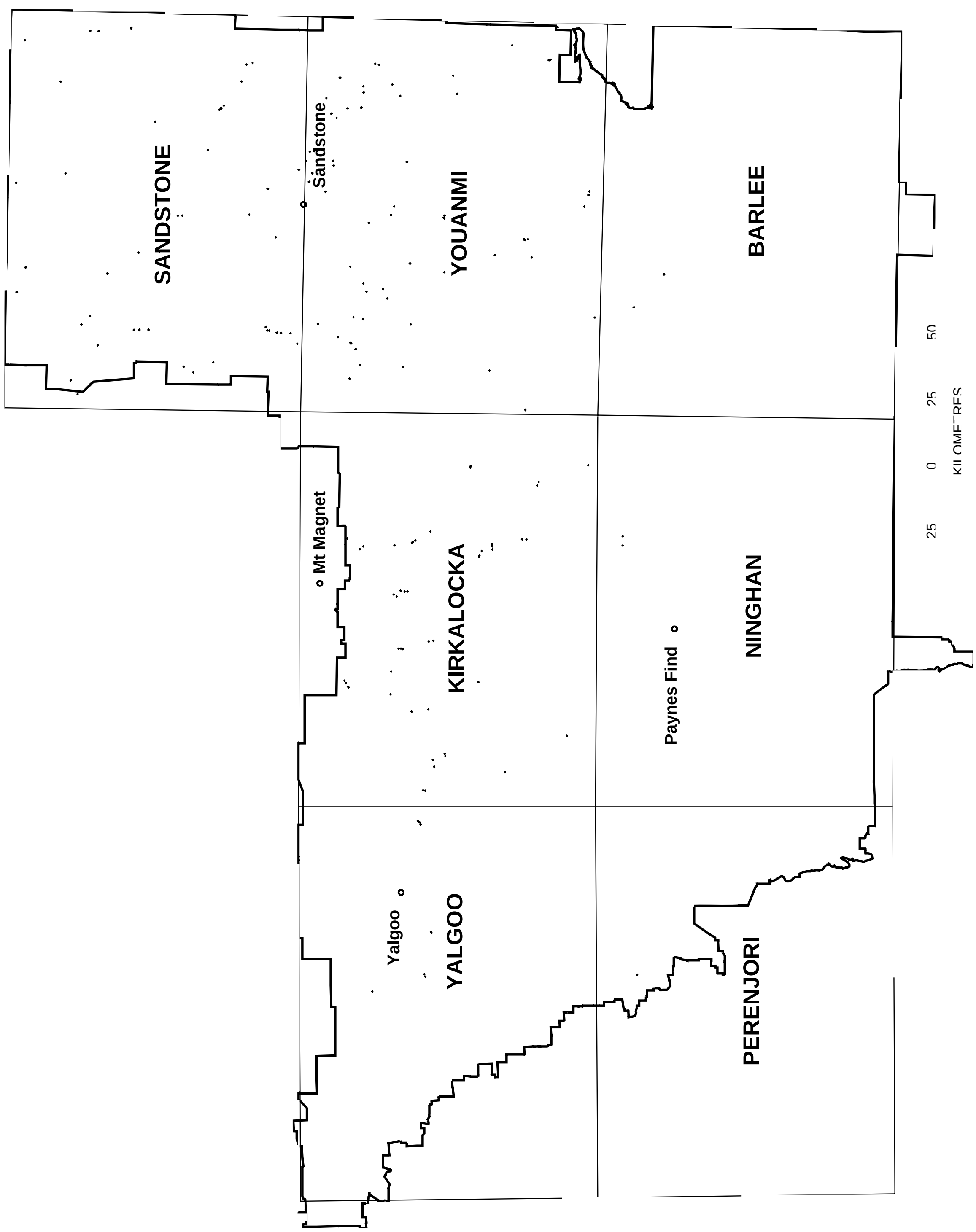

Figure 3. The distribution of condition sites in the survey area

Analysis of data

Traverse records

Traverse assessments, with their land unit and habitat, were entered into a database. As the assessment points had been recorded using a GPS, the points could be referenced onto the land system resource maps. In this way the pastoral lease, paddock name and land system in which each point lay could be verified with the lease, paddock and land system identified during traversing and amended as necessary.

Summaries of the traverse assessments were made by sorting the data on the attributes for which information was required. For example tallies of the land units and habitats within each land system which assisted in developing land system descriptions, and summaries of the condition of pastoral leases, land systems, land units and habitats in the survey area. Land system area and condition statements for individual pastoral leases in the survey area have been published separately (Van Vreeswyk and Godden 1998).

Inventory site data

Inventory site data were used to build detailed descriptions of land systems, land units, soil and vegetation. These are presented in the main chapters of this report. The data were entered onto a computer and sorted using the Paradox database package. The databases were then linked to the resource maps, allowing interrogation.

Condition site data

The condition site data were entered onto a computer database, and analysed using the PATN statistical package (Belbin 1989). The sites provide quantitative information which was analysed, particularly with respect to impacts from grazing. The results of the condition site analysis can be found in the ecological assessment chapter.

Map production

The land systems were finalised using the knowledge gained during fieldwork, and the land system boundaries were reinterpreted on the aerial photographs. These were then transferred to 1:100,000 scale map sheet overlays and digitised using Intergraph computer equipment. Verification plots of the digitised boundaries were produced at 1:50,000 scale for checking against the original land system boundaries on the aerial photos.

A member of the rangeland survey team digitising land system boundaries

Topographical and cultural information covering the survey area was loaded onto the computer system and updated from information collected during field work. Land system boundaries were overlain on this background information. Maps were edited to make all features and text clear and legends were added.

Resource information has previously been presented as a series of published 1:250,000 scale land system maps. With the increased access to computer mapping facilities, and increased budget restrictions, it was decided to provide one 1:500,000 scale land system map to accompany this report. If clients require more detail, maps can be requested at a larger scale. Special purpose maps can be produced displaying any of the data requested by the client as all information has been captured in a multi-layered and geographically referenced digital format. Not all of the data collected during the field work of this survey is presented in this report or on the accompanying map. More detailed information and maps are available on request from Agriculture Western Australia.

In addition to the 1:500,000 regional map DOLA has also produced station plans at a scale of 1:100,000 for each of the pastoral leases within the survey area. In the past these plans have been produced as line maps, for this survey their quality has been greatly improved and they are now available to leaseholders as full colour maps.

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Geomorphology

A.L. Payne and H.J.R. Pringle

Introduction

The geomorphology of the survey area is briefly described in terms of its morphotectonic setting at a continental and regional scale. Land surface types are described with reference to their component land systems. Landscape evolution is briefly discussed in terms of Cenozoic alteration of the morphotectonic setting and the interactions between land use and landscape processes are considered.

The morphotectonic setting

In geological terms the survey area falls within the Western Gneiss Terrain and the Murchison and Southern Cross Provinces of the Yilgarn Craton (Gee *et al.* 1981).

Physiographically the area falls within the Salinaland Plateau, the Murchison Plateau and the Woodrarrung Hills of the Yilgarn Plateau Province (Figure 1 and Table 1). In the far north-west a very small part of the survey area falls within the Yaringa Sandplain of the Western Coastlands Province. All these physiographic regions fall within the Western Plateau Division (Jennings and Mabbutt 1986).

Table 1. Brief description of physiographic divisions in the survey area

Salinaland Plateau	–	sandplains and lateritic breakaways; granitic and alluvial plains; ridges of metamorphic rocks and granite hills and rises; calcretes, large salt lakes and dunes along valleys
Murchison Plateau	–	mainly granitic plains with out-going drainage; broken by ridges of metamorphic rocks
Woodrarrung Hills	–	low rounded ridges of folded metamorphics

A major drainage divide traverses the survey area in a generally north-south direction west of Sandstone and Lake Barlee. Drainage east of this divide is largely endoreic through the Raeside Palaeoriver (van de Graaff *et al.* 1977). This salt lake chain drains south eastwards, occasionally flowing through to Lake Boonderoo on the edge of the Nullarbor Plain after very large rainfall events (Figure 2).

West of the drainage divide channelled drainage is more common and better developed but is still mostly endoreic. The Warne River is a tributary to Lake Moore, which in turn is part of a salt lake system terminating in a series of lakes along the Darling Fault north of the Moore River. A small section of the Greenough River and its catchment occurs in the far north-west of the survey area. This flows into the Indian Ocean south of Geraldton.

The regional geology is characterised by broad expanses of granitoid rocks interspersed with linear or arcuate arrangements of greenstone formations. The greenstone belts are predominantly mafic and ultra mafic sequences with restricted occurrences of clastic sedimentary rocks and felsic volcanics, all of which are of Archaean age. The granite-greenstone terrain formed between 3,100 and 2,500 million years ago (Trendall 1990) as a result of major phases of complex deformation and associated metamorphism.

In the Murchison Province five major phases of deformation have been recognised (Watkins 1990). An early phase of recumbent folding, and possibly thrusting, was followed by two phases of upright, tight to isoclinal folding which form fold-interference patterns. Finally, two extensive systems of north-east to north-west trending shear zones and faults were developed. All rocks in the province, except post-folding granitoids and late cross-cutting dykes, are metamorphosed.

In the Southern Cross Province the deformation of the granite-greenstone terrain is complex and there is evidence of multiple folding (Griffin 1990). All the rocks have a dominant north-northwest trend. Faults and shear zones trend north-northwest and are generally located at granite-greenstone contact. Metamorphic rocks dominate the northern half of the province which encompasses part of the present survey area.

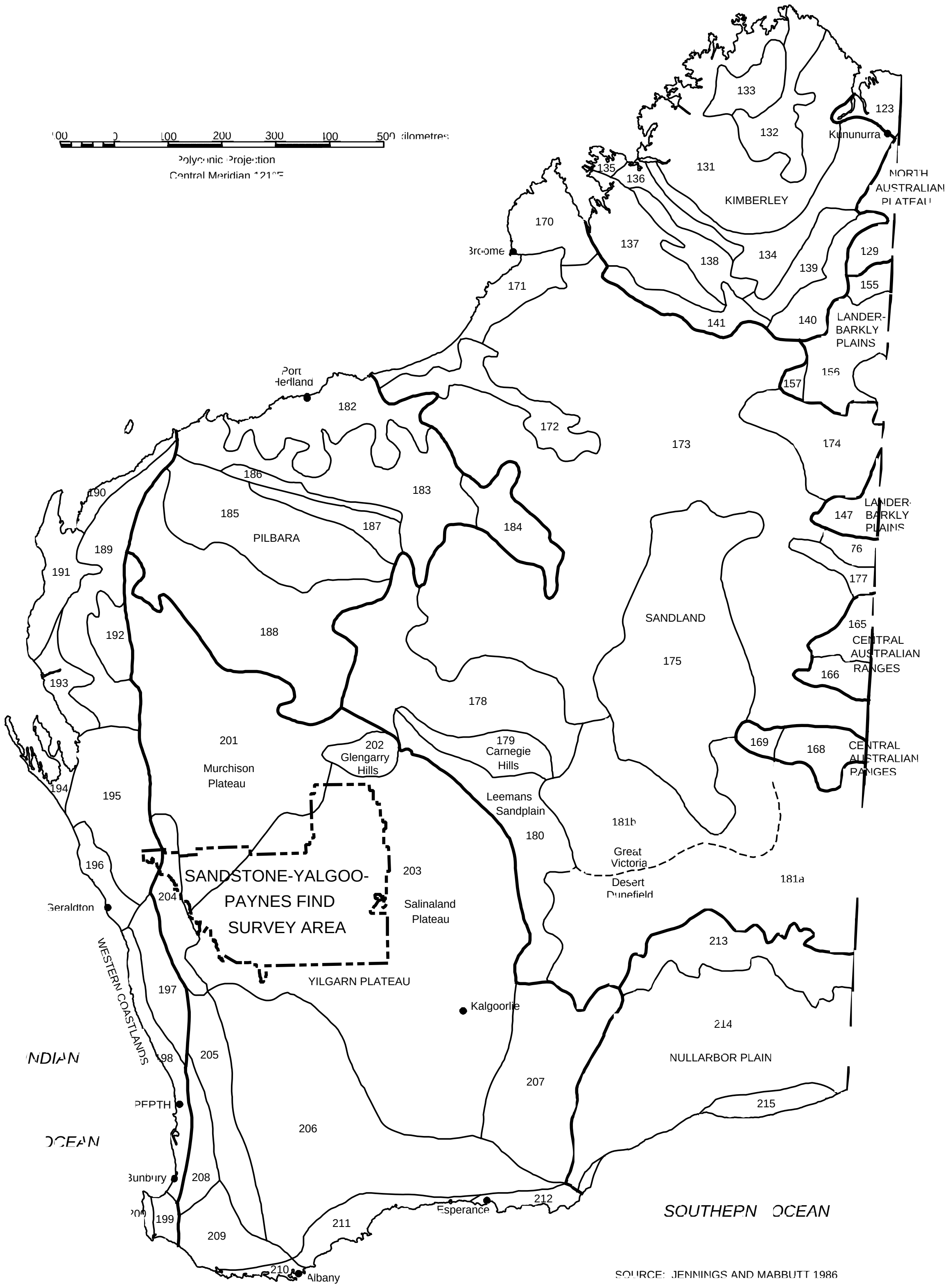
Hills, ridges and regional uplands of Archaean rocks occupy only about 5% of the present survey area but are prominent landmarks in an otherwise level and monotonous landscape of recent depositional surfaces. The Archaean granites occur as low hills, tor fields and large domes surrounded by gritty surfaced plains. Greenstone hills occur either as low weathered rounded hills with associated gentle stony slopes and pediments or as linear hills and ridges.

Banded ironstone formations are commonly associated with greenstone belts. Banded ironstone is resistant to weathering and erosion and forms the spines of prominent ridges extending for many kilometres such as the Mt Manning and Die Hardy Ranges in the south-east of the survey area.

The survey area consists of vast nearly level landscapes only occasionally broken by hills, ridges and domes of granite (such as Bracegonier Hill shown here) or greenstone

Land surface types (groups of land systems)

Eleven land surface types were defined within the survey area and grouped primarily on whether they represent erosional or depositional surfaces and on relief and secondly on genesis and soil and drainage features (Table 2). Colloquialisms are used to maintain brevity in description.



Key to Figure 1:

204	Woodrarrung Hills	low rounded ridges of folded metamorphics
203	Salinaland Plateau	sandplains and laterite breakaways; granitic and alluvial plains; ridges of metamorphic rocks and granitic hills and rises; calcretes, large salt lakes and dunes along valleys.
201	Murchison Plateau	mainly granitic plains with out-going drainage, broken by ridges of metamorphic rocks
195	Yaringa sandplain	sandplain with minor dunes

Figure 1. Physiographic regions of Western Australia

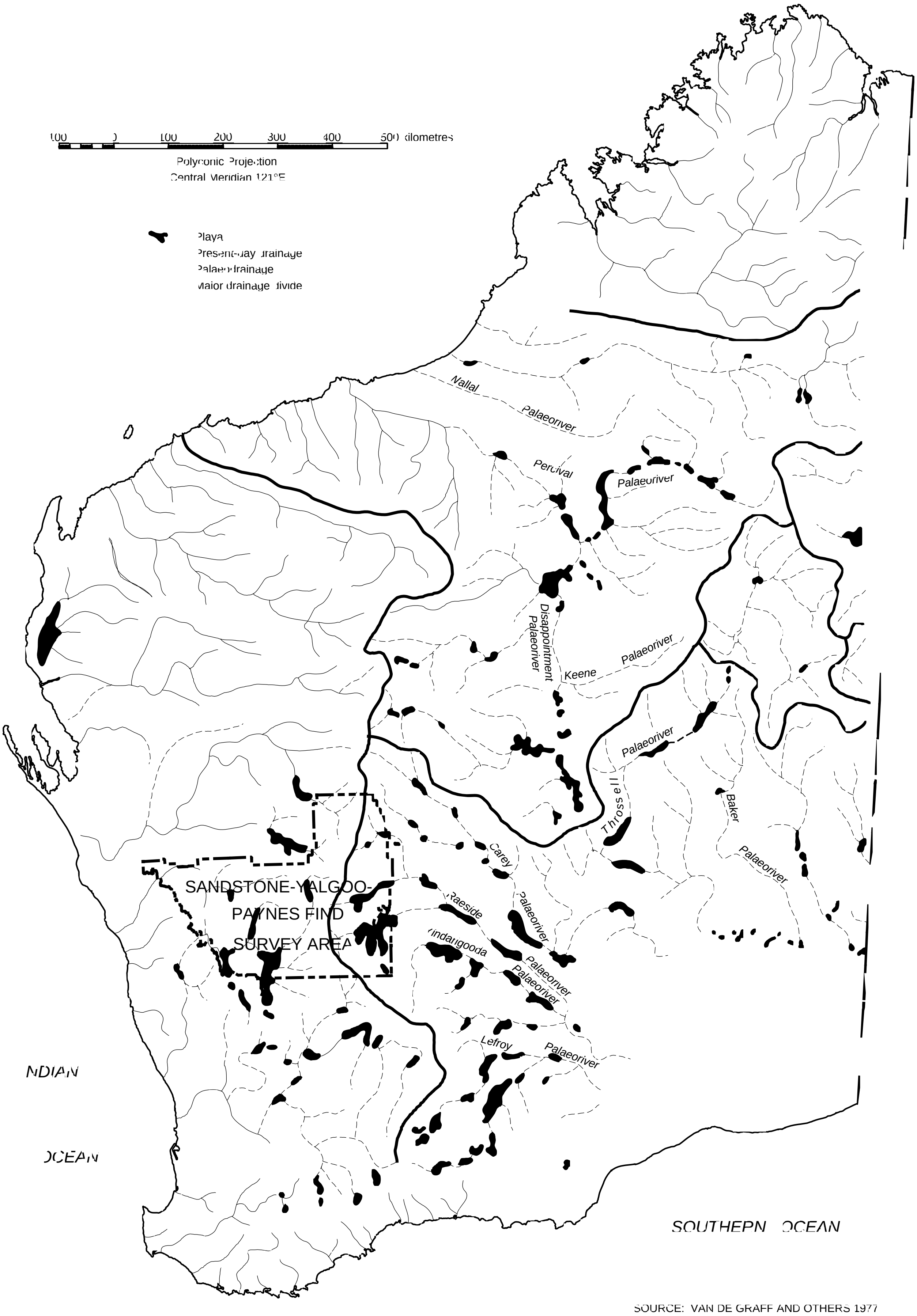


Figure 2. Palaeodrainage systems in Western Australia

Table 2. Land surface types of the Sandstone-Yalgoo rangeland survey area

(a) Predominantly erosional surfaces

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
(i) Hills and ridges	Low to high (30-300 m)	Brooking	Banded iron formation	Strike ridges	East, common
		Dryandra	Banded iron formation	Strike ridges	South-east, common
		Gabanintha	Greenstone, basalt	Rounded hills	Wide, common
		Singleton	Greenstone	Hills, ridges	South-west, uncommon
		Tallering	Banded iron formation	Strike ridges, hills	West, common
		Watson	Sedimentary rocks	Hills	West, uncommon
(ii) Low hills	Low (30-90 m)	Bevon	Limonite, greenstone, colluvium	Low hills and strongly undulating plains	Central and north-east, uncommon
		Graves	Greenstone, alluvium	Low rounded hills	West and south-east, uncommon
		Lawrence	Greenstone, colluvium	Low hills and strike ridges	South-east, rare
		Mulline	Greenstone	Low rounded hills	Mainly south-east, uncommon
		Naluthanna	Gabbro	Low hills, tor fields	Mainly central, common
		Norie	Granite	Low hills, tor fields	Wide, common
		Teutonic	Felsic intrusives and extrusives	Linear hills	Central north, uncommon
		Wiluna	Greenstone, limonite, colluvium, alluvium	Low hills and stony plains	Mainly north-east, common
(iii) Breakaways and lower plains	Very low (9-30 m)	Euchre	Granite, alluvium	Very low breakaways, saline footslopes and restricted alluvial plains	South, common
		Gumbreak	Granite, alluvium	Large breakaways, stony plains and saline alluvial plains	Mainly east, common
		Hootanui	Limonite, greenstone, alluvium	Breakaway, saline gravelly alluvial plains	Mainly central, uncommon
		Narryer	Gneiss, greenstone, colluvium	Low breakaways, rises and extensive stony plains	North-west and central, rare
		Sherwood	Granite, colluvium	Large breakaways and stony plains	Wide, common
		Waguin	Granite, sand	Very low breakaways, stony plains, sandplain	Wide, common
		Yilgangi	Limonite, mafic metamorphic rocks, alluvium	Low breakaways, saline gravelly alluvial plains	West and east, rare

Table 2. – continued . . .

(a) Predominantly erosional surfaces (continued)

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
(iv) Stony plains, gritty-surfaced plains and low rises	Very low (9-30 m)	Bandy	Granite	Low small granite outcrops	Wide, common
		Challenge	Granite	Low tors, occasional breakaways, gritty surfaced plains	Wide, common
		Felix	Felsic volcanics, colluvium	Stony quartz plains	Mainly north-east, uncommon
		Gransal	Granite, colluvium	Saline stony plains	Wide, common
		Moriarty	Limonite, greenstone, colluvium	Low rises, stony plains	South-west, south-east, common
		Nallex	Gabbro, colluvium	Gently undulating stony plains	Central, common
		Nerramyne	Granite, limonite, sand and sandy plains	Low rises, gravelly	West, common
		Nubev	Limonite, greenstone, colluvium	Low rises, gravelly plains, saline alluvial tracts	Wide, uncommon
		Olympic	Granite, limonite, sand	Low rises, gritty surfaced plains, gravelly sandplain	South-west, common
		Violet	Limonite, greenstone, alluvium	Gently undulating gravelly or stony plains	Wide, common
		Windarra	Granite, colluvium	Stony quartz plains	North-east, common
		Yarrameedie	Greenstone, colluvium	Undulating stony interfluves	North-east, uncommon

(b) Predominantly depositional surfaces

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
(v) Hardpan wash plains	Extremely low (<9 m)	Bunny	Alluvium, sand	Hardpan plains with wanderrie banks	North-west, rare
		Hamilton	Alluvium, granite	Hardpan plains with incised drainage lines	Wide, uncommon
		Jundee	Alluvium	Gravelly hardpan plains	Wide, common
		Monk	Alluvium, sand	Hardpan plains with wanderrie banks in lower sections	Mainly east, common
		Rainbow	Alluvium	Hardpan plains	Wide, uncommon
		Ranch	Alluvium	Wide drainage tracts	Wide, uncommon
		Tindalarra	Alluvium	Hardpan plains with saline central drainage tracts	West, common
		Woodline	Alluvium, sand	Sandy surfaces over hardpan	Central and north-east, common
		Yalluwin	Alluvium	Hardpan drainage tracts with braided channels	Wide, uncommon
		Yanganoo	Alluvium, sand	Hardpan plains grading to sandplain on margins	Mainly north-east, common

Table 2. – continued . . .

b) Predominantly depositional surfaces (continued)

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
(vi) Plains with deeper, coarser soils than (v)	Extremely low (<9 m)	Ararak	Alluvium, sand	Plains with mantles of ironstone gravel	East, rare
		Desdemona	Alluvium, sand	Plains with sandy surfaces	East, rare
		Doney	Alluvium, sand	Sandy plains	South, common
		Illaara	Eluvium	Plains with mantles of ironstone gravel	South, uncommon
		Pindar	Alluvium, sand	Unchanneled drainage zones through sandplain	West and south, common
		Tealtoo	Eluvium, sand	Gravelly plains	West and south-east, common
		Yowie	Alluvium, sand	Plains with sandy surfaces	Wide, common
(vii) Plains with saline alluvium (occasionally non-saline)	Extremely low (< 9 m)	Austin	Alluvium,colluvium	Stony plains	North, rare
		Campsite	Alluvium, colluvium	Alluvial plains and gently undulating upper tracts	South, uncommon
		Ero	Alluvium	Tributary flood plains	Mainly central, common
		Joy	Alluvium	Alluvial fans	East, rare
		Marlow	Alluvium	Alluvial (mostly non-saline) plains with drainage foci	Central, rare
		Merbla	Alluvium	Gilgai alluvial plains	Central, common
		Monitor	Alluvium	Alluvial fans	North-east, uncommon
		Racecourse	Alluvium, calcrete	Wide unchanneled drainage tracts	West, rare
		Roderick	Alluvium	Riverine plains with small circular drainage foci	Wild, rare
		Skipper	Alluvium, sand	Alluvial plains, sandy banks	Central, rare
		Steer	Alluvium, colluvium	Gravelly alluvial plains	North-east, uncommon
		Tango	Alluvium	Gravelly alluvial plains	Central and north-east, uncommon
		Wilson	Alluvium	Flood plains and major creeklines	Wide, rare
		Yewin	Alluvium	Flood plains, alluvial plains	North-west, uncommon
(viii) Plains with calcareous red earths	Extremely low (< 9 m)	Deadman	Alluvium, calcrete, sand	Sandy plains and plains with calcrete rubble	South-east, common
(ix) Calcreted palaeo – drainages	Extremely low (<9 m)	Cosmo	Alluvium, calcrete, sand	Calcrete platforms in sandplain	North-east, uncommon
		Cunyu	Alluvium, calcrete	Calcrete platforms	Wide, uncommon
		Melaleuca	Alluvium, calcrete, sand	Swamps, drainage foci, sandy banks	Mainly north-east, uncommon
		Mileura	Alluvium, calcrete	Calcrete platforms with saline alluvium	Wide, common

Table 2. – continued . . .

b) Predominantly depositional surfaces (continued)

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
(x) Salt lakes	Extremely low (<9 m)	Carnegie	Alluvium, sand, gypsum	Bare lakebeds, saline alluvial plains	Wide, common
(xi) Sandplains	Extremely low (< 9 m)	Bannar	Sand, minor alluvium	Sandplain, gravelly sandplain	South, common
		Bullimore	Sand, minor alluvium	Extensive sandplain	North-east, common
		Joseph	Sand, gravel	Undulating gravelly sandplain	West and south, common
		Kalli	Sand, gravel	Elevated, gently undulating sandplain	Wide, common
		Marmion	Sand, minor alluvium	Extensive undulating sandplain	Central east, common
		Tyrrell	Sand, minor alluvium	Level sandplain	Central east, common

(i) Hills and ridges

The common rock types associated with prominent hills and ridges in the survey area are greenstones, basalt, banded ironstone, fine-grained sedimentary rocks and minor felsic volcanics. This surface type occupies about 3% of the survey area and the land systems comprising it are:

Brooking: Conspicuous banded ironstone and jaspilite ridges and hills with hillslopes of variable country rock, relief up to 60 m (occasionally more), generally shallow stony acidic to neutral soils are common on hill slopes.

Dryandra: Very similar to Brooking system, differing mainly in the vegetation it supports; relief up to 150 m or more. It is restricted to the south-east of the survey area where it occurs as the Mt Manning and Die Hardy Ranges.

Gabanintha: Rounded hills and ridges (relief up to 130 m) of greenstones, basalt and banded ironstone, gentle slopes and stony lower plains; incised more or less rectangular drainage patterns.

Singleton: Large hills and ranges of greenstones with relief up to 120 m, prominent in the landscape in central parts of the survey area (e.g. Mt Singleton).

Tallering: Prominent linear ridges and hills of banded ironstone, dolerite and sedimentary rocks, relief up to 200 m but commonly much less; occurs in the west of the survey area (e.g. Tallering Peak and Warriedar Hill).

Watson: Hills, rises and gravelly plains based on fine grained sedimentary rocks, also schist and some felsic volcanics; relief up to 140 m but usually much less.

(ii) Low hills

This land surface occupies a little more than 2% of the survey area and is based on granite, greenstone, gabbro, felsic intrusive and extrusive rocks and limonite. Relief is low (30-90 m) but the hills are prominent above the surrounding plains. The land systems of this surface type are:

Bevon: Irregular low hills, plateaux and occasional minor breakaways with limonite, very stony lower colluvial slopes, undulating gravelly plains with sandy soil profiles and narrow drainage tracts.

Graves: Low rounded greenstone and basalt hills and low rises with narrow alluvial tracts.

Lawrence: Low greenstone hills and banded ironstone strike ridges. Similar to the Brooking system except relief is generally more subdued and soils are highly calcareous. A minor system occurring only in the far south-east.

Mulline: Low hills and rises on weathered greenstone and basalt and gravelly lower plains supporting black oak woodlands and mulga tall shrublands.

Naluthanna: Low gabbro hills, ridges and tor fields, footslopes and lower stony plains with colluvial mantles, narrow gilgaied drainage floors with shallow meandering channels.

Norie: Hills, domes and tor fields of unweathered granite with gently sloping gritty surfaced lower plains; tributary drainage patterns.

Teutonic: Hills of felsic extrusive rocks (occasionally intrusive) with narrow, sometimes incised drainage lines and occasional low rises with limonite rubble mantles. This system is generally associated with greenstone belts.

Wiluna: Low greenstone hills and ridges with occasional limonitic plateau remnants and breakaways, rounded lower stony slopes and saline stony interfluves dissected by shallow valleys and alluvial drainage floors.

(iii) Breakaways and lower plains

Breakaways are most extensive and best developed in the granite domain where they consist of a duricrust of silcrete or

indurated granite over deeply weathered granite. Duricrusts in the greenstone domain are generally ferricrete. There are usually short saline footslopes down slope of breakaway scree slopes with variable plains further down slope. The variable lower plains often characterise the component land systems of this land surface. The land systems of this land surface type (which occupies nearly 8% of the survey area) are:

Euchre: Low breakaways on granite with short footslopes and lower alluvial plains.

Gumbreak: Breakaways (up to 25 m relief) on granite and extensive lower alluvial plains with texture contrast soils which locally have a mantle of stone.

Hootanui: Breakaways (up to 30 m relief) and low hills based on weathered greenstone and felsic extrusive rocks with extensive, saline, gravelly lower alluvial plains and drainage floors.

Narryer: Low breakaways and rises on gneiss, greenstone and other rocks with extensive very gently inclined stony lower plains. Is restricted to only two localities in the survey area.

Sherwood: Breakaways with up to 30 m relief on granite, often with silcrete or ferricrete duricrusts, footslopes with tributary drainage patterns giving way down slope to pediments. This system is widely distributed.

Waguin: Irregular, poorly developed breakaways based on weathered granite, short footslopes and plains below breakaways and patches of sandplain. Distributed as small isolates within sandplain land systems.

Yilgangi: Breakaways (up to 10 m relief) on greenstone and associated rocks with saline footslopes giving way down slope to gravelly alluvial plains with integrated drainage into adjacent ancient drainage systems (lake country).

(iv) Stony plains, gritty-surfaced plains and low rises

These are predominantly erosional surfaces of very low relief (9-30 m) characterised by mantles of lag and colluvium. Quartz is widespread as a mantle component, whilst ironstone and greenstone mantles characterise the greenstone domain and silcrete, lateritic gravels and decomposed granite mantles are found below granite outcrops. This surface type occupies about 11% of the survey area and component land systems are:

Bandy: Irregular low granite outcrops and tors to 15 m relief surrounded by narrow, very gently inclined plains with skeletal soils on granite; frequently occurs as small isolates within sandplain systems. Widely distributed through the survey area.

Challenge: Extensive plains with skeletal soils on granite, stony plains, occasional low tors and breakaways, tributary drainage patterns.

Felix: Very gently undulating plains with quartz lag; based on felsic volcanic rocks, deeply weathered locally, and hardpan on lower plains. Occasional narrow, unincised drainage tracts. Mainly restricted to the north-east of the survey area.

Gransal: Level to very gently undulating saline stony plains, low rises, occasional incipient breakaways and lower alluvial plains on deeply weathered granite.

Moriarty: Low rises with local pockets of lateritic duricurst on weathered greenstone, very gently undulating plains with stony lag and alluvial plains with texture contrast soils.

Nallex: Gently undulating stony plains.

Nerramyne: Undulating plains of sand, gravel and weathered granite with low remnant plateaux, breakaways and rises. This system occurs widely in western parts of the survey area.

Nubev: Rises with ferricrete duricrusts, undulating plains with stone mantles and wide (>500 m) drainage floors with texture contrast soils.

Olympic: Irregular plains on granite and limonite; occasional granite tors, stripped remnant plateaux surfaces and minor breakaways; level to gently undulating gravelly surfaced plains, stony plains and gravelly sand sheets; sparse tributary drainage patterns with narrow alluvial floors.

Violet: Gently undulating plains and rises with mantles of ironstone and gravel, occasional incipient breakaways and generally sparse and unintegrated drainage tracts. Relief to 15 m.

Windarra: Quartz mantled plains based on granite with a thin veneer of hardpan in lower, nearly level areas. Drainage patterns are approximately parallel and generally unincised. There are also occasional low rises of granite.

Yarrameedie: Pediplains with dense mantles of ironstone and metamorphic rocks; sparse parallel drainage patterns grading into lower alluvial fans and drainage floors down slope.

(v) Alluvial plains subject to intermittent sheet flow, with shallow neutral to acid soils on hardpan (‘hardpan wash plains’)

These plains, which occupy about 19% of the survey area, are very gently inclined to nearly level and found extensively between salt lakes and erosional surfaces. Downslope of erosional surfaces in the greenstone domain they usually have a mantle of fine ironstone grit or small pebbles. The land systems of this surface type are:

Bunny: Level to very gently inclined alluvial plains with broad sandy wanderrie banks and patches of sandplain. Occurs only as one very small area in the north-west of the survey area as an outlier from the adjoining Murchison region.

Hamilton: Level to very gently undulating interfluves with incised dendritic drainage lines in upper sectors becoming parallel down slope. This system in the granitoid domain represents the transition from pediments to depositional plains.

Jundee: Extensive alluvial plains with fine ironstone gravel mantles, upper alluvial plains with colluvial mantles and occasional sand banks in lower sectors. Usually found down slope of erosional greenstone terrain.

Monk: Alluvial plains in the granite domain with sub-parallel drainage lanes and characterised by sandy tracts and wanderrie banks of variable extent in lower parts of the system.

Rainbow: Level to very gently inclined alluvial plains with shallow loam soils over hardpan, often with a fine ironstone gravel mantle, and occasional unincised drainage lanes receiving more concentrated flow.

Ranch: Clearly defined broad, generally unchanneled drainage tracts (receiving very concentrated run-on from large granitic upper catchments) through sandplain, draining into salt lakes. Further characterised by occasional small sand sheets and small circular clay pans.

Tindalarra: Extensive, very gently inclined alluvial plains with shallow loamy soils over hardpan, wanderrie sandy banks, and saline central through drainage tracts with saline texture contrast soils and incised drainage channels. A widespread system in central and western parts of the survey area.

Woodline: Very gently inclined alluvial plains with sandy and loamy soils over hardpan; also sparse more concentrated drainage tracts, mostly unchanneled, forming diffuse tributary patterns.

Yalluwin: Very gently inclined plains usually below greenstone and laterite terrain and subject to intense intermittent run-on; mantles of ironstone pebbles and frequent small braided channels shallowly incised into hardpan.

Yanganoo: Very gently inclined alluvial plains with shallow loamy soils over hardpan, sandy tracts and central drainage zones receiving more concentrated sheet flow; receives run-on generally from adjacent granite breakaway systems. Often grades into sandplain in the east of the area.

(vi) Plains receiving diffuse sheet flow and with deep sandy loam to sand soils

These plains are often found on the lower margins of sandplains where they are subject to weak sheet flow following rain which is dispersed and largely absorbed within the system. This land surface type occupies about 13.3% of the survey area and land systems included in it are:

Ararak: Level to gently undulating sandy plains with mantles of fine ironstone gravel.

Desdemona: Sandy surfaced plains with negligible surface drainage features, often occurring adjacent to sandplain in areas receiving weak run-on. Very restricted occurrence in the central east.

Doney: Drainage plains (occasionally with calcareous subsoil pan) carrying weak unchannelled flow and with scattered drainage foci.

Illaara: Very gently undulating plains with ironstone lag over loamy soils and local slightly elevated plains with finer textured soils and calcrete rubble mantles; occasional irregular and unchanneled narrow drainage tracts.

Pindar: Very gently inclined loamy drainage plains and broad drainage corridors between sandplain surfaces.

Tealtoo: Level to gently undulating loamy and sandy plains with mantles of ironstone gravel and pebbles, very few drainage features.

Yowie: Sandy plains with negligible surface drainage features, similar to the Desdemona system, but supporting different vegetation (a denser acacia tall shrub stratum with common mallee eucalypts and sparser wanderrie grass communities). The system is widely distributed and is the largest in the survey occupying nearly 10% of the total area.

(vii) Alluvial plains mostly with saline texture contrast and/or clay soils

These plains are found in depositional areas, often as distributary fans. They are associated with alluvial plains down slope of substantial greenstone sub-catchments and major creeks. The land systems of this land surface type (which occupies about 2% of the survey area) are:

Austin: Nearly level stony plains with low rises and scattered drainage foci and associated sparse sluggish drainage tracts. Occurs only as one very small area in the north as an outlier from the adjoining Murchison region.

Campsite: Very gently inclined plains receiving sheet wash from mafic hills, gently undulating calcareous stony upper plains (erosional) and occasional narrow concentrated drainage tracts. This system occurs only in the south-east of the survey area.

Ero: Very gently inclined tributary flood plains on hardpan, with numerous small drainage foci and claypans and central through drainage tracts with channels.

Joy: Nearly level plains with small creeklines and sandy banks. A minor system restricted to a few locations in the east.

Marlow: Nearly level plains with numerous small discrete drainage foci and claypans and scattered sandy banks. Similar to the Roderick system except that the vegetation is much less halophytic.

Merbla: Nearly level plains with gilgai clay soils, also plains with stony (mostly quartz) mantles and sluggish internal drainage zones with small meandering channels. Associated with gabbro based surfaces of the Nallex and Naluthanna systems in the central north of the survey area.

Monitor: Distributary alluvial fan system based on hardpan frequently receiving concentrated run-on from greenstones; consisting of minor upper channels, grading into alluvial plains with gradational to texture contrast soils and broad drainage tracts and sump areas occasionally with clay soils.

Racecourse: Nearly level broad plains and unchanneled drainage tracts with minor calcrete platforms and occasional drainage foci and claypans. Occurs only as a single area in the north-west.

Roderick: Nearly level plains with saline alluvium characterised by numerous round claypans and discrete vegetated drainage foci; minor sandy banks and occasional channels.

Skipper: Internally drained plains with saline alluvium and numerous small sandy banks. Occurs only at one location in the centre of the survey area.

Steer: Very gently inclined plains with saline alluvium and ferruginous gravel veneers, and occasional gravelly rises, scattered circular drainage foci and central drainage tracts carrying concentrated flow.

Tango: Nearly level to gently inclined plains with non-saline and saline (in lower parts) alluvium over hardpan generally with mantles of ironstone gravel and pebbles.

Wilson: Major creek system with distributary fans consisting of sandy bedload deposits adjacent to channels giving way down slope to extensive lower alluvial plains with texture contrast soils.

Yewin: Nearly level plains with saline alluvium associated with the Greenough and Salt Rivers and subject to fairly regular flooding; many features of through and internal drainage, variable drainage foci, claypans and anastomosing drainage tracts, minor calcrete rises and platforms of kopi; major channels.

(viii) Plains with deep calcareous red earths flanking salt lakes

These plains are found in the south-east of the survey area where they occur up slope of salt lakes. They differ markedly from the more extensive alluvial plains on red brown hardpan to the north in having deeper, sandier, calcareous soils with calcrete inclusions and frequently calcrete rather than siliceous soil pans. They are also subject to considerably less sheet flow and have very poorly developed drainage features. This land surface type occupies only about 0.2% of the survey area.

Deadman: Nearly level to gently undulating plains mostly with no defined drainage. Calcrete nodules occur through the soil and calcrete rubble characterises higher areas with shallower soil.

(ix) Calcreted valley fill deposits associated with former more active drainage axes

The drainage pattern of most of the area is characterised by previously integrated river systems which have become networks of variably connected salt lakes. Deposition of marine and terrestrial sediments effectively choked these drainage networks, which have been variably subjected to aeolian deposition of sand and groundwater precipitation of calcrete. The land systems of this land surface type (which occupies about 1.3% of the survey area) are:

Cosmo: Low calcrete platforms and plains with calcrete rubble in ancient drainage axes which have been extensively overlain by red aeolian sand.

Cunyu: Low calcrete platforms in ancient drainage valleys with shallow, poorly developed soils and alluvial plains with non-saline uniform loamy soils and minor saline texture contrast soils.

Melaleuca: Densely vegetated drainage foci and sandy banks generally overlying calcrete, often flanking salt lake systems and grading into sandplain.

Mileura: Calcrete valley fills with calcrete platforms to 2 m relief above extensive plains with saline alluvium (supporting halophytic shrublands).

(x) Salt lakes

The large salt lakes and their fringing tributary plains represent the lowest surfaces in the survey area and have resulted from the infill and choking of once more active palaeodrainage systems. The lakes act as drainage termini and evaporative basins for run-on water from their catchments; only after exceptionally heavy rainfall are the lake chains linked by surface flow. The land system of this surface type (9.2% of the survey area) is:

Carnegie: Extensive lake beds with fringing kopi dunes, sand lunettes and banks and saline alluvial plains with texture contrast soils.

(xi) Sandplains

Sandplains are very extensive away from greenstone belts and are found in a number of positions in the landscape. They are the dominant land surface in the south-west of the survey area, where they occur as extensive plains with occasional sand dunes or granite outcrops. In more dissected terrain they occur on the back slopes of breakaways in the granite domain. They are also common adjacent to salt lakes. Many of the sandplains have red sand, there are also extensive areas with buff sand in the south-west. This surface type occupies about 30% of the survey area and component land systems are:

Bannar: Nearly level sandplain. Occurs in the west and south-central parts of the survey area.

Bullimore: Generally very gently sloping to broadly undulating plains of red sand with occasional near parallel sand dunes. Supports spinifex hummock grasslands which distinguishes it from most other sandplain systems (except Marmion and Tyrrell). An extensive system but found only in the north-east.

Joseph: Nearly level to gently undulating gravelly rises and yellow sandplain characterised by very dense shrub vegetation. Widespread in the west and south of the survey area.

Kalli: Perched, nearly level to gently undulating red sandplain often on back slopes of breakaways and edged by stripped surfaces on laterite and granite. Widely distributed.

Marmion: Very gently undulating sandplain with occasional low rises with laterite profiles, minor granite outcrop.

Tyrrell: Nearly level red sandplain in the south-east of the region.

The evolution of landforms in the Cenozoic

Today's land surfaces described above have evolved by processes of weathering, erosion and deposition acting during the Tertiary (Beckman 1983 in Wyroll 1988) on the previous landforms of the Yilgarn block. Tertiary climates were markedly different from those of today being initially much warmer and more humid (McGowran 1979). These conditions resulted in deep weathering of country rock which prepared the landscape for subsequent erosion and the formation of laterites or 'Walther profiles' (Walther 1915) over extensive areas.

Early perceptions (Jutson 1934, Woolnough 1927) were of a lateritic surface of almost continental extent (the 'Old Plateau') which has subsequently been back stripped to produce the 'New Plateau' surface. This 'Old Plateau'/'New Plateau' model has been used to interpret landform evolution in the Wiluna-Meekatharra area (Mabbutt 1961, 1963) to the north of the present survey area. More recent perceptions of geomorphological processes, based on technological advances such as remote sensing and sediment dating, suggest that the early model is an oversimplification (Wasson 1982, Ollier *et al.* 1988). However, the fundamental concept of etchplanation operating by retreat at breakaway faces reducing the extent of *in situ* deeply weathered rock and exposing fresh rock is still relevant.

Explanations for the different genesis of the landforms seen today depend largely on the theory of ferricrete formation which in itself is a contentious issue. One opinion is that ferricretes and silcretes form in areas of high relief as a result of *in situ* vertical mobilisation of iron and silica and its precipitation near the surface (e.g. Churchward 1977). Others such as Ollier *et al.* (1988, 1991) suggest that duricrusts develop by lateral transport of silica and iron in groundwaters and cementation in areas of low relief and that the duricrust attains positive relief by subsequent inversion. Within the survey area duricrusts occur commonly as prominent breakaway lines overlying deeply weathered material in upper parts of the landscape. Ollier *et al.* (1988) view the extensive occurrences of hardpan (the Wiluna Hardpan of Bettenay and Churchward 1974) on lower slopes and sheet wash plains as incipient duricrust. In the survey area the main types of duricrust are silcrete and indurated weathered granite in the granite domain and ferricrete in the greenstone domain.

Following the tropical climates which resulted in extensive deep weathering (Wyrwoll and Glover 1988) and the formation of laterites during the Early and Mid-Tertiary came the onset of a much more arid and fluctuating climate. Bowler (1976) suggests that the onset of aridity occurred in the Pliocene. Generally more arid climates extended into the Quaternary but with numerous fluctuations between cooler and drier periods and warmer and wetter periods.

The impact of these climate changes in the late Cenozoic and in particular in the Quaternary has been on the effectiveness of weathering, erosional and depositional processes. It seems most likely that rates of denudation on the Yilgarn block in late Cenozoic have been very slow (van de Graaff 1981, Wyrwoll 1988). Landscapes have obviously been modified by etchplanation, scarp retreat and local alluvial and aeolian deposition but the effect of drier climates has been to preserve, rather than substantially modify landscapes. Nonetheless indications are that the evolution of present landscapes has been complex involving repeated cycles of denudation, transportation and deposition proceeding at rates controlled by climate variability and which are continuing today. Such models of genesis (Ollier *et al.* 1988, Ollier 1991) involve multiple plantation surfaces and repeated inversions of relief.

Erosional landforms and processes

Ten erosional surfaces have been described previously (Churchward 1977) for certain parts of this survey area. Six are derived from granitic rocks and four from greenstone and associated rocks. These surfaces can be correlated with the land surfaces and land systems described in this report.

In this survey area some of the most prominent erosional landforms are ridges based on resistant banded ironstone formations and hills on relatively unaltered basalts. Examples on banded ironstone are the ranges (Dryandra land system) in the south-east and Tallering Peak (453 m, Tallering land system) in the north-west. An example on basalt is Mt Singleton (677 m, Singleton land system) in the centre of the survey area. These monadnocks rise above the ‘Old Plateau’ and are resistant remnants left after differential weathering and erosion of Archaean surfaces.

Other striking erosional landforms are breakaway escarpments which may be 30 m above the surrounding plains. Breakaways represent regional erosion fronts in which highly weathered saprolite, capped by a duricrust of indurated saprolite, silcrete or ferricrete is eroded by lateral retreat. Breakaways are commonly well developed on granitic rocks (parts of the Sherwood and Gumbreak land systems) in the survey area. Breakaways in the greenstone provenance occur on land systems such as Wiluna and Hootanui.

Stony plains with surface mantles of quartz, ironstone or greenstone rocks are common in upper parts of the landscape. These erosional surfaces shed water onto other surfaces such as hardpan wash plains downslope.

Other erosional landforms are low domes, tors and corestone masses of fresh granite (e.g. Norie land system) which occur as regional watersheds mostly in central and northern parts of the survey area. These resistant batholith masses have been exposed after more or less complete stripping of the adjacent weathered mantle. The shape and orientation of domes and rock clusters are influenced by jointing and the direction of structural belts. Dome surfaces are often partly covered with exfoliation plates, produced by ‘onion skin’ weathering, and joint blocks.

Depositional landforms and processes

(a) Several very large salt lakes (e.g. Lake Barlee, Lake Moore) occupy parts of palaeodrainage systems within the survey area. They contain terrestrial sediments dated back to the Eocene including saline and gypseous lacustrine and fluviatile clays, wind blown kopi and quartz sands. Hocking and Cockbain (1990) suggest that the drainage systems were active in the Early Tertiary and that significant flow ceased before the Late Miocene. When active the systems drained towards the Eucla or Perth Basins; today drainage is internal.

Salt lakes occupy the lowest parts of the landscape. They are the remains of old river systems now choked with sediments and which fill with water from the surrounding country after heavy rains.

(b) Sandplains are extensive and widely distributed through the survey area (Bannar, Bullimore, Joseph, Kalli, Marmion and Tyrrell land systems). They can occur as elevated fragmented 'Old Plateau' surfaces overlying Tertiary laterite and weathered granite or as very extensive sheets overlying alluvium and hardpan usually at >1 m deep. Churchward's (1977) observation in the east of the survey that sand particle size declined down the gentle back slope of a breakaway is consistent with the fluvial sedimentological explanation of sandplain distribution and formation supported by Bettenay and Hingston (1964) and Mulcahy (1967) (cf Glassford 1980). Occasional parallel, linear dunes or small dune field occur in some parts of the Marmion and Bullimore systems (less commonly on the Kalli system) and indicate that aeolian processes have also been significant most likely a number of times during arid periods in the Quaternary.

Red and buff coloured sandplains occupy about 30% of the survey area and are widely distributed. They have quite dense vegetation and deep soils with high infiltration rates and contribute very little run-off to adjacent surface types.

(c) Calcreted valley fill deposits are common in palaeodrainage lines and represent old valley floors whose alluvium has been replaced by carbonate. According to Hocking and Cockbain (1990) the formation of these groundwater calcretes requires conditions of low, irregular rainfall, high evaporation, little surface drainage or run off, and a shallow water table with sluggish groundwater movement. Such conditions commenced in the Pliocene and there is evidence that calcretes are still forming in recent alluvium.

In the survey area the calcrete bodies are generally undissected and form mounds (elevated only to a few metres) separated by alluvial floors and locally masked by superficial aeolian sand deposits.

(d) Plains with semi-consolidated to consolidated alluvial sediments ('hardpan') are extensive throughout the survey area. In the Wiluna area to the north-east of the present survey area Bettenay and Churchward (1974) formalised the name Wiluna Hardpan for a highly indurated form of these sediments. Hardpan is likely to have formed during alternating periods of flooding and dessication and the transport of iron and silicates, derived from weathering up slope, in groundwater to the zone of precipitation. The time of commencement of its formation is probably broadly contemporaneous with groundwater calcretes. Ollier *et al.* (1988) view hardpan as incipient duricrust, attaining its relief by subsequent inversion.

These plains which have very shallow loamy soils overlying the hardpan are subject to intermittent, broad sheet flow. Some drainage corridors receive more concentrated through flow than the surrounding plains and have occasional channels and creeklines.

Some of these plains show patterns of vegetation banding with relatively large areas with very scattered vegetation ('intergroves') alternating with smaller arcuate areas of dense vegetation ('groves'). This patterning is associated with gently inclined surfaces receiving overland sheet flow and is further controlled (see Mabbutt and Fanning 1987) by soil type and differential rates of water infiltration on soils of variable depth over hardpan.

Almost level hardpan wash plains occupy about 19% of the survey area. They are subject to sheet water flows which shed to lower saline plains and salt lake systems. Surface hydrology processes are extremely important in maintaining ecological integrity of these plains.

(e) Broad depositional plains often underlain by hardpan or gravel but with deeper, sandier soils than (d) are common in the survey area (e.g. Yowie, Tealtoo, Woodline land systems). As with the shallower hardpan plains they are subject to sheet flow but, because of their sandy nature, absorb nearly all of this. They exhibit very few organised drainage features and contribute little through flow to surfaces further down slope. Fluvial processes are evident as indistinct fan patterns on aerial photographs, occasional weak groving patterns and slightly heavier textured soils in the lowest tracts.

(f) Plains with more or less saline alluvium are widespread in the survey area although nowhere near as extensive as the hardpan (generally non-saline) plains described in (d). They receive sheet flow and/or concentrated channelled through flow from adjacent granitic and greenstone uplands. They frequently occur in distributary

fans and active floodplains developed from overbank flooding from channelled tracts such as those associated with the Warne River on Pindabunna station and Salt River on Barnong station.

These plains commonly have moderately abundant lag surfaces of pebbles and gravels typically of ironstone, greenstone and quartz near the greenstone domains and granite and quartz in granitic domains. More distant from stony catchments they have little or no mantling (e.g. Ero, Marlow and Roderick land systems). The plains contain variable sedimentary sequences including old bedload deposits from prior streams and often overlie hardpan or are partly calcreted. Frequently the plains have numerous small drainage foci and swampy depressions representing areas of lowest relative relief which are characterised by heavier soils, than in adjacent areas.

(g) Piedmont tracts adjacent to greenstone hills often consist of granite rocks overlain by alluvium and colluvium, including stones derived from the greenstone domain (e.g. Yarameedie land system or the Hanson unit of Churchward 1977). Pediments in the granitic domain consist of convex slopes and low interfluves with quartz pebbles and stones interspersed with drainage floors with alluvium of irregular depth over granite.

In summary, the present landforms in the survey area comprise about one quarter erosional surfaces and three quarters depositional surfaces. They consist of extensive sandplain (locally with near parallel sand dunes), sub-parallel greenstone hill belts, breakaways (most frequently, but not exclusively, in the granitic domain) with lower pediments which pass into extensive, level to very gently inclined sheetwash plains draining into salt lakes. Relief is subdued and drainage is generally disorganised and endoreic. This regional characterisation reflects a very old landscape that has not experienced the rejuvenation of glacial events in the Pleistocene that have overwhelming influenced current landforms in the northern hemisphere. Here, the landform patterns are best appreciated in terms of a morphotectonic setting of greenstone belts surrounded by extensive granitoid expanses that have undergone deep weathering in the Mid to Early Cenozoic and have been largely preserved with the onset of aridity in the Late Cenozoic, with some modification by erosion and deposition.

Land use impacts on landscape processes

There has been little research on the impacts of land use on landscape processes in Western Australian rangelands. However, this and similar surveys (e.g. Wilcox and McKinnon 1972, Payne *et al.* 1982, 1987) document those lands on which natural erosion processes have been accelerated by inappropriate land uses. The survey of the Gascoyne River catchment (Wilcox and McKinnon 1972) was undertaken largely because of off-site effects i.e. severe flooding in Carnarvon which was suggested as occurring because of excess run-off from a degraded catchment.

Hills and adjacent undulating plains

The scattered to very scattered nature of perennial vegetation and very shallow stony soils in hilly greenstone areas and adjacent undulating plains results in little infiltration and high levels of run-off. Accelerated erosion in this terrain is rare as the soil is protected by abundant stony mantles. However, on some lower footslopes where soils are deeper the removal of the stony mantle along tracks or grid lines can result in accelerated erosion in the form of rills, gutters or shallow gullies.

Breakaway footslopes

The breakaway footslopes in both granite and greenstone domains are inherently unstable and have tributary rills, microterracing and redistribution of soil material even when well vegetated. The slopes are areas experiencing the most active natural erosion in the survey area as they represent regional erosional fronts developing in deeply weathered material immediately blow breakaway escarpments. Where loss of perennial shrubs has occurred (which is commonly the case) erosion processes are inevitably accelerated. A variety of erosion types including scalding, sheeting, microterracing, rilling, guttering and occasionally gullying are widespread. For practical purposes the degradation may be irreversible.

The extensive loss of soil on these fragile areas clearly illustrates the importance of minimising grazing activity. Tracks, pipeline alignments, mineral exploration grid lines and any other disturbances should avoid these areas if at all possible. These areas warrant further research to investigate cover thresholds and trampling impacts on soil stability.

Pediments

Pediments below greenstone and granite hills, rises and breakaways are usually level to gently undulating, have a protective cover of stone, low vegetation cover (usually less than 15%) and poor infiltration characteristics, but are generally not susceptible to erosion, even when plant cover is reduced. This is largely a result of the protection provided by the stony mantle.

Narrow drainage areas which occupy only a small proportion of this terrain support moderately close mulga tall shrublands or, where the soils are more saline, mixed shrublands with scattered halophytic low shrubs. The former areas are mostly unincised and are not usually susceptible to soil erosion. The latter areas (such as in parts of the Sherwood, Wiluna and Violet land systems) are moderately susceptible to degradation and accelerated erosion.

Distributary alluvial fans

Distributary alluvial fans (Monitor and parts of Wilson land systems) are relatively uncommon in the survey area but are significant in that they are invariably degraded and eroded. Slopes on these tracts are low (usually less than 1%) but the soil surface is without the protective stony cover of the pediments found up slope and the soils are inherently sensitive duplex types. A compounding factor is that the vegetation on these areas often includes palatable succulent chenopod shrubs favoured by stock and has generally been severely degraded by overgrazing earlier this century. Thus, with reduced plant cover and high levels of run-off from adjacent uplands, the fans are susceptible to soil erosion. Hardpan is often exposed where soil removal has been complete, elsewhere there are often microterraces and scalds, with guttering or gullying in areas receiving more concentrated flow.

Saline alluvial plains

These level to very gently inclined plains are inherently resistant to erosion where they have abundant mantles of pebbles and gravel but are susceptible to water erosion where surface mantles are absent. Many alluvial plains without mantles support dense vegetation. Here the evidence of erosion is limited to the movement and deposition of silt and fine sand, the deposition of clay veneers in sink zones and obvious trails and accumulations of litter. When in good condition water and nutrients are conserved and cycled within the system (the 'fertile patch' concept, Tongway 1994). In these alluvial systems the individual bush mounds and small drainage foci are the fertile sites where water infiltration rates, nutrient accumulations and biological activities are at their maximum.

Where vegetative cover is depleted by preferential grazing or other disturbances erosion is accelerated and natural cycling processes dislocated. Erosion is evident as surface sheeting, microterracing, scalding, scouring and guttering. Loss of shrubs result in the breakdown and eventual dispersion of bush mounds and the loss of the system's ability to trap and utilise water and nutrients.

Some degraded alluvial plains are susceptible to invasion by unpalatable native shrubs but this is not regarded as a major problem in the survey area.

Sheetwash (hardpan) plains

Most of the extensive hardpan alluvial plains in the area are subject to intermittent sheet flow, are level to very gently inclined and support scattered mulga tall shrublands whose plant cover is only very locally subject to reduction by overgrazing. Cryptogamic crusting is well developed and widespread on these plains and confers stability to soil surfaces. These conditions render the plains fairly immune to soil erosion except in some localised more concentrated through-flow drainage tracts where vegetation is disturbed.

Surface hydrology processes are extremely important in maintaining the ecological integrity of these systems. Any disturbance that restricts, diverts or concentrates surface sheet flows will effect (often adversely) vegetation communities. For example, these plains are susceptible to water starvation caused by inappropriately located or constructed tracks and roads. In such cases vegetation may decline down slope of the impedance to flow and expose the soil to wind erosion. Tracks should allow for the regular and frequent passage of water down slope so as to reduce the risk of water build-up and high energy discharge where it breaks through the track. Similarly spoon drains should be used to disperse water moving along tracks so as to minimise track erosion and down slope water starvation. Construction of tracks in the same direction as sheet flow should be avoided as this can cause water starvation problems and track erosion which may spread laterally by microterracing away from the track.

Some of these plains support obvious fertile patches in the form of more or less distinct groves or arcuate bands of vegetation which are denser than that surrounding. The groves receive and retain sheet flow from up slope intergrove areas and are areas of high biological activity including being favoured feeding and resting places for domestic stock and native animals. Although generally stable, groves can be degraded by excessive grazing or by alterations to surface water flows. In extreme cases shrubs and trees die, water is no longer retained, nutrients are lost and the grove structure collapses.

Inappropriately located tracks on plains subject to sheet flow can alter flow characteristics and result in erosion down to the hardpan

Alluvial plains adjacent to salt lakes

Broad, level to very gently inclined alluvial plains (Carnegie land system) occur near salt lakes. Soils are duplex types with sandy surface horizons which enhance infiltration and have well developed and widespread cryptogamic crusts. They receive sheet flow from adjacent hardpan plains and other surfaces. Vegetation is typically a low shrubland of saltbush or bluebush species with prominent development of shrub mounds (fertile patches) around the plants. The plains are fairly resistant to erosion unless plant cover is considerably reduced and the soil surface crust excessively broken. In this case patchy wind scalding and thin sheeting by water can occur in the inter shrub spaces.

Sandplains

The use of fire as a grazing management tool in spinifex hummock grasslands is fairly common in the east and north-central parts of the survey area. Occasionally accelerated wind erosion occurs after burning but after rain vegetative cover re-establishes rapidly and stabilises these sandy sites.

In summary, the Sandstone-Yalgoo-Paynes Find area has a variety of natural characteristics which help protect the landscape from the impacts of inappropriate land use practices. Examples of these characteristics are the widespread occurrence of relatively dense (>20% projected foliar cover) tall shrublands comprising species which are largely unaffected by grazing, stony surface mantles, cryptogamic soil crusts and the nearly level nature of much of the terrain.

The areas in which the landscape is most susceptible to inappropriate land use are breakaway footslopes, distributary fans in the upper sectors of alluvial plains, alluvial plains subject to channelised through flow and flooding, hardpan wash plains where hydrological processes are disrupted and sites supporting vegetation types which are highly preferred by herbivores. The impact of land use in these areas has not been quantified in terms of increased run-off velocities, soil loss rates, sediment yields, vegetation cover thresholds and other such variables inherently reflective of landscape processes and ecosystem health.

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Soils

P. Hennig

The survey area is located within the Yilgarn Craton, an Archaean shield, mainly of gneiss and granite-based geology with some metamorphic (greenstone) belts and palaeodrainages which are now large salt lakes. The granite and gneiss are mainly medium to coarse-grained. There is also occasional basalt, amphibolite, gabbro and jaspilite. The landscape was first described by Jutson (1934).

The soils are derived from old lateritic profiles which were formed in the Tertiary period (approximately 50 million years ago), in what was believed to be a wetter and possibly tropical environment. Relic lateritic remnants displayed today as breakaways or mesas suggest that the original land surface was higher than at present. Deep chemical (laterisation) and physical weathering of the original undulating land surface over millions of years plus a slow change to a drier environment has led to current landforms. In many cases the soil was developed from weathered and eroded material thus masking its origin.

Mabbutt *et al.* (1963) and more recently Ollier *et al.* (1988) suggest how the current landscapes were formed, and although their views differ, both hypotheses suggest deep chemical weathering and subsequent large scale erosion shaped the land. General stripping of the original land surface has exposed fresh igneous, metamorphic and to a lesser extent sedimentary rock, with different rock types weathering at different rates.

On the backslopes of the breakaways, sand sheets occur as wind modified or *in situ* remnants of deeply weathered lateritic profiles.

Immediately below other outcrops, the colluvial slopes and peneplains give way to broad plains carrying sheet flow down extremely shallow gradients. These wash plains consists of alluvium derived from pallid zone materials of the lateritic profile and partly weathered granite, gneiss and greenstones. Soil derived from granitic areas is generally siliceous with increasing clay content with depth, while the greenstone-based soils are finer textured and occasionally contain fine ironstone gravels.

Deep accumulations of sand as banks of soil occur intermittently on some wash plains. These banks are of aeolian origin which have been further shaped by overland water flow.

A siliceous red-brown hardpan occurs throughout most of the region except on the south-west and southern margins to the wheatbelt. This is an almost continuous layer varying from 1 to 30 m in depth underlying many soils. The pan is often at a depth of 30 to 70 cm but may be exposed on some very shallow hardpan plains and especially in drainage channels.

The Warne and Greenough Rivers are the only major rivers in the survey area. Overland sheet flow is terminated partly by infiltration but mostly by discharge via minor tributaries that drain internally into the palaeodrainages linked to five major lakes – Barlee, Noondie, Mason, Moore and Monger.

Previous surveys

The soils of the survey area have previously been described and mapped at a scale of 1:2,000,000 by Bettenay *et al.* in 1967 (Sheet 6); Northcote *et al.* in 1967 (Sheet 5) and Northcote *et al.* in 1968 (Sheet 10) as part of The Atlas of Australian Soils, providing a general overview of distribution. In summary these soils are:

Sands with rock material below the A2 horizon (Uc4.1). Map unit JJ17

Red sands with an earthy fabric (Uc5.21). Map units AB5, Ab6, Ab7

Yellow sands with an earthy fabric (Uc5.22). Map units AC11, AC12

Ironstone gravels with a sandy matrix (Uc5.22). Map unit AC1

Loamy soils of minimal development (Um1). Map unit SV4

Shallow earthy loams with red-brown hardpan (Um5.31). Map units BE1, BE2, BE3, BE5

Shallow dense loamy soils (Um5.41). Map unit F8

Shallow coherent and porous loamy soils (Um5.51). Map unit Fa4

Grey-brown calcareous loamy earths (Gc1.12). Map unit LB11

Red earths with neutral reaction trends (Gn2.12). Map units My42, My43, My45, My46, My49, My50

Red earths with alkaline reaction trends (Gn2.13). Map unit Mx10

Yellow earths with acid reaction trends (Gn2.21). Map unit Ms8

Ironstone gravels with a yellow earth matrix (Gn2.21). Map unit MZ1

Hardsetting loamy soils with red subsoils (Dr2.33). Map units Oc34, Oc35

Teakle (1936) and Bettenay and Churchward (1974) described the red-brown siliceous hardpan which is unique to the region. Churchward (1977) also mapped and described part of the Sandstone and Youanmi 1:250,000 map sheets as part of a larger resource inventory.

Areas to the north and east of the survey area have been previously described by Mabbutt *et al.* (1963), Curry *et al.* (1994) and Pringle *et al.* (1994), all of whom conducted regional resource inventories of landforms, soils and vegetation.

In this report, the land unit descriptions detail the distribution of soil types within the land systems.

Field sampling methods

Eight hundred soils were described using the criteria of the Australian Soil and Land Survey Field Handbook (McDonald *et al.* 1990).

Soil pits were dug at inventory sites to a depth of 50 cm after which a 50 mm graduated soil auger was used to

retrieve soil to a depth of 1 m or underlying rock or hardpan. Samples were laid out to determine different soil layers.

Soil textures were determined for the fine earth fraction (<2 mm) after sieving out coarse fragments. The sieved fraction was moistened and the behaviour of the kneaded soil recorded. Field texturing gives an indication of the proportions of sand, silt and clay and was conducted as required to determine the thickness of soil layers. Soil textures range from sand (<5% clay) to heavy clay (>50% clay). Textures were determined down the profile firstly to separate the major soil layers into A, B, C or D horizons, where the A horizon is the topsoil, the B horizon is the subsoil, the C horizon is weathered rock and the D horizon mostly represents red-brown hardpan. Further subdivision of the major soil horizons was required.

Soil colour was determined in the field using a moistened fresh soil aggregate and comparison with standard soil colour charts (Munsell Color Co. 1954).

Consistence, a measure of soil bonding, was determined by compressing a 20 mm undisturbed soil unit. Fabric was assessed by examining the appearance of an undisturbed soil mass to determine its pedality. The appearance of pores, voids, coarse sand grains, earthiness or structured regular soil aggregates determines the fabric. The classifications are sandy, earthy, smooth or rough ped, derived from the Australian Soil and Land Survey Field Handbook (McDonald *et al.* 1990).

Soil structure is related to soil fabric and was determined using a hand lens. The presence or absence, size and shape of soil aggregates (particle clusters held together by forces of inter-particle bonds), were recorded.

The parent material, substrate or underlying rock was determined either from geological maps or more often careful examination of the material retrieved via the soil auger.

The soil pH was measured in the field using the paste calorimetric method described by Raupach and Tucker (1959). Carbonates were detected by using drops of hydrochloric acid, effervescence indicating presence of calcium carbonate.

The electrical conductivity (EC) of soil horizons was obtained in the field using a portable EC meter using 10 g of soil in 50 mL of distilled water. This was used to indicate the total soluble salts present.

Other recordings taken were the shape, size and abundance of coarse fragments, soft segregations or crystals within a profile plus surface features such as mantle, outcrop, cryptogam crusting.

Several soil samples were taken from each major soil group and sent to the Agricultural Chemistry Laboratories of the Chemistry Centre (WA) for analysis of nitrogen, phosphorus, exchangeable cations, cation exchange capacity, pH, electrical conductivity and particle size distribution. A typical soil profile analysis is presented for each major soil group.

The soil depth classes are:

<25 cm	very shallow
25-50 cm	shallow
50-100 cm	moderately deep
>100 cm	deep

Soil classification

The soils were classified using two systems – A Factual Key to the Recognition of Australian Soils (Northcote 1979) and the Australian Soil Classification (Isbell 1996).

The Northcote system is a morphological classification based on observable soil profile features, using a hierarchical bifurcating principle to separate soils. This alphanumeric coding first separates soils according to their (non) uniformity, then differences in the individual soil layers.

The Australian Soil Classification is more closely associated with systems used overseas and has classes defined on the basis of diagnostic horizons and their arrangement in the vertical sequence as seen in an exposed soil profile.

Soil groups and soil types

Soil descriptions are presented as survey specific soil types, of which 25 within twelve groups were identified and described in detail.

The correlation between soil groups and their component soil types for this survey and Soil Groups of Western Australia (Schoknecht in press.) is given in Table 1.

Group 1 – Stony soils (45 sites)

These are shallow (<50 cm) and characterised by a lack of soil development and a dense mantle of rocks, boulders and rock outcrop. They occur on hillcrests, slopes, ridges and rises. Textures vary greatly, dependent on parent material. Stony soils formed on greenstones tend to be more clayey than those of granite origin. Greenstone-based soils have surface textures of fine sandy loam to loam, with subsoil textures of loam to clay loam, while granite-based soil textures vary from coarse clayey sand to sandy loam or sandy clay loam. Some soils are very shallow or skeletal. Rock outcrop and coarse fragments within the soil profile may be common to abundant (10 to >50%). Within some greenstone hill systems, decomposing parent rock may produce calcareous soils, however these appear to be minor.

The stony soils are mostly acidic (field pH 5.0 to 7.0), apart from those affected by the calcareous influence, which are alkaline (>8.5). Surfaces are generally firm to occasionally hardsetting, with common (10-50%) cryptogam crusting. Soil colour ranges from dark reddish brown (2.5YR 3/3) to red (2.5YR 4/8) or yellowish red (5YR 4/6). Toward the footslopes of the hill or upland systems they intergrade and give way to shallow stony red earths (subgroup 5b).

Australian Soil Classifications: Paralithic and minor Lithic Leptic Rudosols

Principal Profile Forms: Uc1.12, Uc1.23, Uc1.43, Uc5.21, Um1.23, Um1.31, Um1.43, Um5.41 and Um5.51

Erosion susceptibility: Low due to protective mantle and rock outcrop

Table 1. Comparison of survey soil types with Soil Groups of Western Australia (Schoknecht in press.)

Soil Groups of Western Australia	Soil Group and Type (this survey)
ROCKY OR STONY SOILS	
Stony soil	1 Stony soils
SANDY-SURFACED SOILS	
	2 Shallow sands
Red shallow sand	2a Shallow coarse red clayey sands
Red shallow sand	2b Shallow red clayey sands with ferruginous gravel
Red shallow sand	2c Shallow red clayey sands on calcrete
Red shallow sand	2d Shallow red clayey sands
Yellow/brown shallow sand	2e Shallow yellow clayey sands
	3 Deep sands
Red deep sand	3a Deep red clayey sands
Yellow deep sand	3b Deep yellow clayey sands
Red deep sand	3c Deep red sands
	4 Sandy earths
Red sandy earth	4 Sandy-surfaced red earths
LOAMY-SURFACED SOILS	
	5 Shallow loams
Calcareous shallow loam	5a Shallow calcareous loams
Red shallow loam	5b Shallow stony red earths
Red shallow loam	5c Shallow red earths
Red-brown hardpan shallow loam	5d Shallow hardpan loams
	6 Loamy earths
Red loamy earth	6a Deep red earths
Calcareous loamy earth	6b Deep calcareous loamy earths
SANDY TO LOAMY-SURFACED DUPLEX SOILS	
	7 Shallow duplexes
Red shallow sandy duplex	7a Shallow duplexes on granite
Red shallow loamy duplex	7b Shallow duplexes on greenstone
Red shallow sandy duplex	7c Shallow duplexes on hardpan
	8 Deep duplexes
Red deep sandy duplex	8 Deep sandy duplexes
CLAYEY-SURFACED SOILS (CLAYEY THROUGHOUT)	
	9 Non-cracking clays
Red/brown non-cracking clay	9a Shallow clays
Red/brown non-cracking clay	9b Deep clays
	10 Cracking clays
Massive cracking clay	10 Cracking clays
WET SOILS	
	11 Salt lake soils
Salt lake wet soil	11 Highly saline soils
OTHER SOILS	
Other soils	12 Juvenile soils

Representative profile

Soil type: Stony soil (over greenstone)

Land system: Hootanui (site 304)

Land unit: low rise

Habitat: *Stony ironstone mulga shrubland* (SIMS)

Soil surface/condition: hardsetting with infrequent (<10%) cryptogamic crusting

Surface mantle: abundant (>50%) medium pebbles (6-20 mm) of angular mixed greenstone

Associated rock outcrop: infrequent (<10%) metamorphics

Australian Soil Classification: Ferric Leptic Rudosol

Principal Profile Form: Um1.43

Profile description

Depth (cm)	Horizon	Description
0-10	A	Dark reddish brown (2.5YR 3/4) fine sandy loam; massive structure; earthy fabric; partial slaking; non-dispersive; non-calcareous, very weak consistence; non-sticky; non-plastic; very few to few (2-10%) medium to coarse (2-20 mm) subrounded lateritic coarse fragments; field pH 6.0.
10+	R	Hard Tertiary laterite.

Group 2 – Shallow sands

2a) Shallow coarse red clayey sands (36 sites) are normally 5-30 cm deep and found on gentle slopes below and among granite outcrops or breakaway plateaux. Textures are mostly loamy sand, clayey sand or coarse clayey sand with abundant coarse fragments of granite and quartz, overlying granite. The soil is formed locally, the rock below shows decomposition through the absence of some softer elements in granite such as feldspar and mica. Rock outcrop may be common (10-50%), and field soil reaction is acidic (field pH 6.0-6.5). Typically the soil surface is about 40-70% loose coarse quartz sand and granite fragments with the remainder being stabilised with light to moderate (10-50%) cryptogamic crusting, the exception being on the breakaway plateaux where the surface is mostly exposed rock. Colour is dark red (2.5YR 3/6) to red (2.5YR 4/6).

Australian Soil Classifications: Paralithic or Lithic, Leptic Rudosols, minor occurrences of Arenic Rudosols
Principal Profile Forms: Uc5.21, Uc1.43 with occasional Uc1.23
Erosion susceptibility: Low due to extensive rock outcrop and mantle

Representative profile

Soil type: Shallow coarse red clayey sand

Land system: Sherwood (site 16)

Land unit: stony plain

Habitat: *Stony acacia eremophila shrubland* (SAES)

Soil surface/condition: hardsetting with light to moderate (10-50%) cryptogam crusting

Surface mantle: common (10-20%), medium (6-20 mm) subangular granite pebbles

Associated rock outcrop: infrequent <10% granite

Australian Soil Classification: Paralithic Leptic Rudosol

Principal Profile Form: Uc5.21

Profile description

Depth (cm)	Horizon	Description
0-5	A11	Yellowish red (5YR 4/6) clayey sand; massive structure; earthy fabric; non slaking; non-dispersive; weak consistence; non-sticky; non-plastic; non-calcareous; common (10-20%), medium (2-6 mm) coarse fragments of subangular quartz; field pH 6.0; abrupt, smooth boundary.
5-35	A12	Reddish brown (5YR 4/4) clayey coarse sand; massive structure; earthy fabric; partially slaking; partially dispersive; weak consistence; non sticky; non-plastic; non-calcareous; common (10-20%) medium (2-6 mm) coarse fragments of subrounded quartz and few (2-10%) medium (2-6 mm) weathered granite fragments; field pH 6.0.
35+	C	Weathered granite.

2b) Shallow red clayey sands with ferruginous gravel (25 sites) are up to 50 cm deep, occurring within small plains of laterised greenstone-based lower slopes and shallow sandplain or sand sheets. These sands are coherent to weakly coherent, fine-textured clayey sand to fine sandy loam overlying laterised greenstone, banded ironstone, ferruginous gravel or occasionally red-brown siliceous hardpan. On lower slopes, soil reaction is acidic (field pH 6.0) and fine ironstone gravel may cover up to 80% of the firm to hardsetting soil surface. As sandplain or sand sheet units, the soil is acidic (field pH 4.5-6.0) with a soft to firm surface often with a very sparse (<10%) surface layer of fine ironstone gravel. The soil is free draining. Colour ranges from strong brown (7.5YR 5/6) to dark red (2.5YR 3/6).

Australian Soil Classifications: Paralithic and Ferric-Duric Orthic Tenosols, Ferric-Petroferric Orthic Tenosols, Ferric-Petroferric and Duric Leptic Rudosols
Principal Profile Forms: Uc5.21, KS Uc5.21, Uc5.12, Uc1.43, occasionally Uc1.23
Erosion susceptibility: Low due to gravel mantle

Representative profile

Soil type: Shallow red clayey sand with ferruginous gravel

Land system: Jundee (site 318)

Land unit:	lateritic gravel plain
Habitat:	*Hardpan mulga shrubland* (HPMS)
Soil surface/condition:	hardsetting with common (10-50%) cryptogam crusting
Surface mantle:	many (20-50%) small (2-6 mm) pebbles of subangular ironstone
Associated rock outcrop:	nil
Australian Soil Classification:	Duric Leptic Rudosol
Principal Profile Form:	Uc5.21

Profile description

Depth (cm)	Horizon	Description
0-25	A	Dark reddish brown (2.5YR 3/4) loamy sand; massive structure; earthy fabric; partially slaking; non dispersive; very weak consistence; non-sticky; non plastic; non calcareous; common (10-20%), medium (2-6 mm), rounded ferromanganiferous gravels; field pH 6.5.
25+	D	Red-brown siliceous hardpan.

2c) Shallow red clayey sands on calcrete (11 sites) normally 15-50 cm deep overlying calcrete on calcrete platforms or calcrete dominated plains. These soils are medium to fine-textured sandy loam to fine loamy sand. Calcareous coarse fragments occur within the profile increasing with depth. These soils often have a common (10-50%), calcrete mantle of mixed stones and pebbles (5-200 mm). Soil reaction is alkaline (field pH >8.0-10.0) and the soil mass is usually not coherent or occasionally only weakly so. The surface is firm to hardsetting with common (10-50%) to occasionally abundant (>50%), cryptogam crusting. Dark red (2.5YR 3/6) to yellowish brown (5YR 4/6), these soils are associated with calcareous loams and shallow stony red earths (subgroups 5a and 5b).

Australian Soil Classifications: Petrocalcic Leptic Rudosols; Hyperbasic Petrocalcic Calcarosols
Principal Profile Forms: Uc1.13, Uc1.23, Uc1.33, Uc1.43, Uc5.12, Uc5.21
Erosion susceptibility: Generally low due to calcrete mantle and outcrop

Representative profile

Soil type:	Shallow red clayey sand on calcrete
Land system:	Cunyu (site 23)
Land unit:	calcareous platform
Habitat:	*Calcrete platform jam shrubland* (JAMS)
Soil surface/condition:	firm with common (10-50%) cryptogam crusting
Surface mantle:	common (10-20%), medium (6-20 mm) pebbles of angular calcrete
Associated rock outcrop:	infrequent (<10%) calcrete
Australian Soil Classification:	Hyperbasic Petrocalcic Leptic Calcarosol
Principal Profile Form:	Uc1.13

Profile description

Depth (cm)	Horizon	Description
0-15	A	Dark reddish brown (5YR 3/4) sandy loam; massive structure; earthy fabric; completely slaking; completely dispersive; very weak consistence; slightly sticky; non-plastic; highly calcareous; few to common (<20%), medium to coarse (2-20 mm) coarse angular fragments of calcrete; field pH 9.5.
15+	D	Calcareous substrate.

2d) Shallow red clayey sands (81 sites), normally 20-50 cm deep occur as shallow sand banks or sand sheets, overlying red-brown siliceous hardpan, decomposing granite or very occasionally ferruginous gravel, calcrete or greenstone. The sand sheets or banks are marginally higher than the surrounding loamy plains. Textures are generally loamy or clayey sand to sandy loam with marginally higher residual clay contents just above the hardpan. These soils generally have very few to few (<2-10%), fine (2-6 mm), coarse fragments of subangular quartz. Occasional subrounded ferruginous gravels occur in some subsoils. Soil reaction is acidic to neutral (field pH 5.5-7.0). Surfaces are generally soft to firm with only minimal (<10%) cryptogam crusting. Colour is dark red (2.5YR 3/6) to red (2.5YR 4/6). Pseudo-earthy sands (as described in soil type 3a) are a minimal component of this subgroup.

Australian Soil Classifications: Duric, Paralithic Petroferric and Lithic Leptic Rudosols; occasional Arenic Rudosols; Lithic, Duric and Ferric-Petroferric Orthic Tenosols
Principal Profile Forms: Uc1.23, Uc1.43, Uc5.12, Uc5.13, Uc21, Uc5.32 and occasional Uc1/5 (pseudo-earthy)
Erosion susceptibility: Low under existing vegetation; low to moderate wind erosion risk if vegetation cover is reduced or recently burnt; susceptible to gully erosion along poorly planned or maintained tracks.

A stony mantle protects the soil surface from erosion

2e) **Shallow yellow clayey sands (4 sites)** are mostly 20-50 cm deep and occur as shallow sand sheets, overlying ferruginous gravel. Textures are generally loamy or clayey sands with few to common (2-20%), medium to coarse (2-20 mm), subrounded or rounded ferruginous gravels in the upper layers. Gravel content increases (to >50%) with depth. Soil reaction is acidic to neutral (field pH 5.5-6.0). The surfaces vary from firm with common (10-50%) cryptogam crusting to soft with coarse loose sand. Medium to coarse (2-20 mm) ironstone surface gravels are common (10-50%). Colour is strong brown (7.5YR 4/6) to yellowish brown (10YR 5/6).

Australian Soil Classifications: Arenic, Ferric Clastic and Petroferric Leptic Rudosols, Orthic Tenosols
Principal Profile Forms: Uc1.22, KS Uc5.22 and Uc5.22
Erosion susceptibility: Low under existing vegetation

Representative profile

Soil type:	Shallow yellow clayey sand
Land system:	Joseph (site 161)
Land unit:	gravelly sandplain
Habitat:	*Sandplain mixed closed shrubland* (SMCS)
Soil surface/condition:	soft with fine, abundant (10-50%) cryptogam crusting
Surface mantle:	few (2-10%), medium (2-6 mm), pebbles of subrounded ironstone
Associated rock outcrop:	nil
Australian Soil Classification:	Petroferric Leptic Rudosol
Principal Profile Form:	Uc5.22

Profile description

Depth (cm)	Horizon	Description
0-10	A11	Very dark greyish brown (10YR 3/2) clayey sand; single grained structure; sandy fabric; non-slaking; non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; common (15%), coarse (6-20 mm), rounded ironstone gravels; field pH 6.0; sharp boundary.
11-30	A12	Brown to dark brown (7.5YR 4/4) clayey sand; single grained structure; sandy fabric; non-slaking; non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; common (15%), coarse (6-20 mm), rounded ironstone gravels; field pH 6.0; clear boundary.
31-80	B	Yellowish brown (10YR 5/6) clayey sand; single grained structure; sandy fabric; non-slaking; partially dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; common (20%), coarse (6-20 mm), rounded ironstone gravels; field pH 5.5.
80+	R	Lateritic gravel.

Group 3 – Deep sands

3a) **Deep red clayey sands (90 sites)**, mostly over 100 cm deep occurring as extensive sandplains or sand sheets. Where less than 100 cm deep the soils are underlain by red-brown siliceous hardpan, occasionally ferruginous gravels or very occasionally granite or calcrete. They are uniformly textured coherent loamy sands often increasing to sandy loam with an earthy fabric throughout. Surfaces of loose-medium grained sand are soft without cryptogamic crusting and soil reaction is mostly acidic (field pH 5.0-7.0). Coarse fragments of angular quartz are fine (2-6 mm) and very few (<2%) throughout the profile. Ferruginous gravels in the deep subsoils are few. Colour is dark red (2.5YR 3/6) to red (2.5YR 4/6). The appearance of an earthy fabric is sometimes difficult to detect or describe. Scholz and Smolinski (1987) refer to soil which does not conform to Stace *et al.*'s (1968) Siliceous Sand or Earthy Sand Great Soil Groups, and describe an intergrade of this soil type. This intergrade with a sandy and earthy appearance was termed a pseudo-earthy fabric. Some soils occurring on extensive sand sheets, sand plains, sand banks or small dunes conform to the pseudo-earthy description and have been classified into this group.

Australian Soil Classifications: Arenic Rudosols, Duric Leptic Rudosols; Petroferric Leptic Rudosols, Orthic Tenosols
Principal Profile Forms: Uc1.23, Uc1.43, Uc1/5, Uc5.21 and Uc5.11
Erosion susceptibility: Low under existing vegetation; low to moderate wind erosion risk if vegetation cover is reduced or recently burnt; susceptible to gully erosion along poorly planned or maintained tracks

Representative profile

Soil type:	Deep red clayey sand
Land system:	Bullimore (site 30)
Land unit:	sand sheet
Habitat:	*Sandplain spinifex hummock grassland* (SASP)
Soil surface/condition:	soft with infrequent (<10%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Orthic Tenosol or Arenic Rudosol
Principal Profile Form:	Uc5.21

Profile description

Depth (cm)	Horizon	Description
0-5	A11	Dark red (2.5YR 3/6) loamy sand; single grained structure; sandy fabric; non-slaking; non-dispersive; loose consistence; non-sticky; non-plastic; non-calcareous; very few (<2%), medium (2-6 mm), coarse fragments of angular quartz; field pH 6.0; abrupt, smooth boundary.

6-100+	A12	Dark reddish brown (2.5YR 3/4) clayey sand; single grained structure; sandy fabric; partially slaking; non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; no coarse fragments; field pH 6.0.

3b) Deep yellow clayey sands (5 sites) deep (>100 cm) often with ferruginous gravels in the lower subsoils, these soils occur as sandplains on the western and southern margins of the survey area. Textures are uniformly coherent loamy or clayey sands throughout the profile. Topsoil horizons are often stone-free apart from occasional (<5%) ironstone gravels, but subsoils may show increasing (10-50%) amounts of coarse (6-20 mm) ferruginous gravels. Soil reaction is acidic (field pH 5.5-6.0). The soil surface shares both common (10-50%) cryptogamic crusts and zones of loose coarse wind blown sand. Colour ranges from dark to strong brown (7.5YR 4/4 to 7.5YR 4/6) immediately below the surface, to yellowish brown (10YR 5/8) in the subsoil. Some surfaces are very dark greyish brown (10YR 3/2) due to organic staining through accumulated leaf litter below dense vegetation. This group has 'pseudo-earthy' soil types. Deep yellow sands (not sampled) are principally the same as the deep red sand soil type (subgroup 3c), but colour is dominantly yellow rather than red. The soil is free draining and slightly more acid than the deep red loose sands (field pH 4.5-5.5). These soils exist principally as sand dunes, a minor component of the western and southern survey margins occurring only in the extensive yellow sandplains supporting deep yellow sands.

Australian Soil Classifications: Arenic Rudosols and Ferric Orthic Tenosols
Principal Profile Form: Uc5.22, Uc1.22 with occasional Uc1/5 (pseudo-earthy)
Erosion susceptibility: Low under existing vegetation; low to moderate if degraded or after fire.

3c) Deep red sands (4 sites) are normally very deep (>100 cm) occurring as sand dunes within sandplains or on lake systems or large playa margins. Uniformly fine textured sand or less commonly, clayey sand. This soil is non-coherent, lacks significant profile development and has a loose consistency. It is acidic (field pH 4.5-6.0). As with the deep red and deep yellow sands (subgroups 3a and 3b) there is indication of an intergrading pseudo-siliceous soil types where the sand dunes give way to the deep sands of the adjoining sandplain. These soils have no coarse fragments within the profile and loose, soft often mobile surfaces. Colour is dominantly dark red (2.5YR 3/6) to red (2.5YR 4/6).

Australian Soil Classification: Arenic Rudosol
Principal Profile Form: Uc1.23 and Uc1/5 (pseudo-siliceous)
Erosion susceptibility: Low under existing vegetation; moderate to high wind erosion risk after fire; avoid track use through large dunes as vehicular traffic suppresses vegetation establishment and stabilisation.

Representative profile

Soil type:	Deep red sand
Land system:	Bullimore (site 276)
Land unit:	sand dune crest
Habitat:	*Sand dune shrubland* (SDSH)
Soil surface/condition:	loose
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Arenic Rudosol
Principal Profile Form:	Uc1.23

Profile description

Depth (cm)	Horizon	Description
0-15	A11	Dark reddish brown (5YR 3/4) sand; single grained structure; sandy fabric; non-slaking; non-dispersive; loose consistence; non-sticky; non-plastic; non-calcareous; no coarse fragments; field pH 6.0; clear, smooth boundary.
16-100+	A12	Yellowish red (5YR 3/4) sand; single grained structure; sandy fabric; non-slaking; non-dispersive; loose consistence; non-sticky; non-plastic; non-calcareous; no coarse fragments; field pH 6.0.

Group 4 – Sandy earths

Sandy-surfaced red earths (14 sites) are deep (mostly >100 cm) soils with light surface soil textures grading to heavy subsoil textures occasionally underlain by red-brown siliceous hardpan. Sandy red earths occur on sand sheets, sandplains and broad sandy plains receiving diffuse run-on. These soils have surface textures of clayey sand to sandy loam increasing to sandy clay loam or clay loam at depth, and may have sandy, earthy or even a 'pseudo-earthy' (refer to subgroup 3a) fabric. The soil usually contains very few to few (2-10%) inclusions of quartz or occasionally few to very few (2-10%), fine (<6 mm), rounded manganiferous or ferruginous gravels. They are generally acidic to neutral throughout (field pH 6.0-7.5). Cryptogam crusting on the soft to firm soil surface is minimal (<10%). Colour is dark red to red (2.5YR 3/6 to 2.5YR 4/6).

Australian Soil Classifications: Red or Duric Red Kandosols
Principal Profile Form: Gn1.11, Gn1.12, Gn2.11, Gn2.12, occasional Um5.52
Erosion susceptibility: Generally stable under existing vegetation but moderately susceptible to water erosion along poorly planned or maintained tracks

Representative profile

Soil type:	Sandy deep red earth
Land system:	Monk (site 478)
Land unit:	loamy plain
Habitat:	*Wanderrie bank grassy mulga shrubland* (WABS)
Soil surface/condition:	soft with common (10-50%) cryptogam crusting

Surface mantle: nil

Associated rock outcrop: nil

Australian Soil Classification: Red Kandosol

Principal Profile Form: Gn1.12

Profile description

Depth (cm)	Horizon	Description
0-10	A	Dark reddish brown (2.5YR 3/4) clayey sand; single grained structure; sandy fabric; non-slaking; partially dispersive; very weak consistence; non-sticky; non-plastic; non calcareous; few (2-10%), fine (<2 mm), angular coarse fragments of quartz; field pH 6.0; clear, smooth boundary.
11-90	B21	Red (2.5YR 3/6) sandy loam; single grained structure; sandy fabric; non-slaking non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; field pH 9.0; clear smooth boundary.
91-100+	B22	Red (2.5YR 3/6) sandy clay loam; massive structure; earthy fabric; partially slaking; partially dispersive; weak consistence; slightly sticky; slightly plastic, non-calcareous, field pH 7.0.

Group 5 – Shallow loams

5a) Shallow calcareous loams (19 sites), are very shallow to shallow (10-50 cm), highly calcareous, and overlie calcrete associated with major drainage zones or associated with weathered metamorphic rocks. Textures range from fine sandy loam to light sandy clay loam. The soil is very loose and powdery in the dry state and is dominated by few to many (2-50%), medium to extremely coarse (2->60 mm) rounded or angular calcium carbonate fragments and few to common (2-20%), fine to medium (<2-6 mm), soft calcareous segregations. Outcropping calcrete is common and soil reaction is highly alkaline (field pH >9.0). The surface is firm, occasionally with light to moderate (10-50%) cryptogam crusting although the mantle of calcrete fragments and exposed calcrete is more notable. Colour ranges from red (2.5YR 3/6) to dark yellowish brown (10YR 4/6).

Australian Soil Classifications: Supracalcic Calcarosols, Calcic Calcarosols, minor Calcic Red Kandosols
Principal Profile Form: Uc1.13, Uc1.33, Um1.13, Um1.14, Um1.33, Um5.51, Um5.61, Gc1.12, Gc1.21
Erosion susceptibility: Low to moderate

Representative profile

Soil type: Shallow calcareous loam

Land system: Bevon (site 314)

Land unit: low calcareous rise

Habitat: *Stony ironstone mulga shrubland* (SIMS)

Soil surface/condition: hardsetting with infrequent (<10%) cryptogam crusting

Surface mantle: abundant (50-90%), large pebbles (20-60 mm) of subrounded metamorphics

Associated rock outcrop: infrequent (<10%) weathered (calcareous) metamorphics

Australian Soil Classification: Hyperbasic Petrocalcic Leptic Calcarosol

Principal Profile Form: Um1.33

Profile description

Depth (cm)	Horizon	Description
0-10	A	Dark red (2.5YR 3/6) loam; massive structure; earthy fabric; completely slaking; partially dispersive; very weak consistence; non-sticky; non-plastic; highly calcareous; many (30%) coarse (6-20 mm) angular calcareous coarse fragments; common (10-15%) calcareous soft segregations; field pH 9.0; clear boundary.
10+	Crk	Calcrete

5b) Shallow stony red earths (16 sites) are very shallow (<25 cm) to shallow (<50 cm) soils found on hillslopes, low rises and adjoining stony plains. Surface textures range from fine sandy loam to sandy clay loam overlying sandy clay loam or clay loam. Most soils are underlain by banded ironstone, basalt, gabbro or other metamorphic rock. The solum contains varying amounts (2-60%) of fine to extremely coarse (2-100 mm) fragments of quartz or weathering material. The soil has common to abundant (10 to >50%) mantles or outcrops of quartz and metamorphic rock which range in size from pebbles (2-6 mm) to cobbles and boulders (60-200 mm). Soil reaction is mostly neutral (field pH 6.5-7.5) with occasional more alkaline types. The surface among the stony mantle is firm to hardsetting and has a moderate (10-50%) cryptogam crust. Some soils grade into the shallow red earths (subgroup 5c) and the stony soils (group 1).

Australian Soil Classifications: Lithic and Paralithic Leptic Tenosols, Leptic Rudosols, Red Kandosols
Principal Profile Forms: Um1.23, Um1.43, Um5.21, Um5.41, Um5.51
Erosion susceptibility: Low due to protective rock mantle, but susceptible to water erosion along inappropriately planned or maintained tracks

Representative profile

Soil type: Shallow stony red earth

Land system: Tallering (site 104)

Land unit: hillslope

Habitat:	*Stony ironstone acacia shrubland* (SIMS)
Soil surface/condition:	hardsetting
Surface mantle:	many (20-50%), angular mixed metamorphics
Associated rock outcrop:	infrequent (<10%) banded ironstone and mixed metamorphics
Australian Soil Classification:	Paralithic Leptic Rudosol
Principal Profile Form:	Um5.51

Profile description

Depth (cm)	Horizon	Description
0-25	A	Red (2.5YR 4/6) fine sandy loam; massive structure; earthy fabric; completely slaking; non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; very few (<2%), coarse (6-20 mm) angular ferromanganiferous coarse fragments; field pH 5.5; clear, smooth boundary.
25+	C	Weathering banded ironstone.

5c) Shallow red earths (70 sites) are gradational or uniform shallow (<50 cm) soil overlying hardpan or weathered rock. This occurs on the margins of the sheet wash plains, some drainage areas and low rises or upper stony plains. Textures range from sandy loam to light sandy clay loam at the surface to sandy clay loam in the subsoil. Inclusions are restricted to few, fine to medium (<2-6 mm) angular fragments of quartz or rounded ironstone gravels. Soil reaction is mostly neutral (field pH 6.0-7.5). The generally stone-free soil surface is either firm for the lighter textured soils or hardsetting with common (10-50%) cryptogam crusting for the heavier textured types. Some soils are underlain by calcrete or weathered calcareous greenstones and have neutral reaction topsoils (field pH 7.0), with highly alkaline subsoils (field pH >10.0). These soils may be occasionally underlain by ironstone gravels. This soil shares features of the shallow hardpan loams (subgroup 5d) and some shallow stony red earths (subgroup 5a).

Australian Soil Classifications: Red Kandosols, Duric Red Kandosols, Duric Leptic Rudosols, minor Paralithic Lithic Leptic Tenosols; Petroferric Leptic Tenosols, Petroferric Red Kandosols
Principal Profile Forms: Uc1.43, Um1.41, Um5.41, Um5.51, Um5.61, Gn2.11, Gn2.21, Gn3.12
Erosion susceptibility: Topsoils of the lighter sandy loams are moderately susceptible to wind erosion after extensive vegetation removal. Heavier textured topsoils are moderately to highly susceptible to sheet erosion after extensive surface crust decline, especially in the absence of a stony mantle.

5d) Shallow hardpan loams (75 sites) are uniform textured shallow loams overlying red-brown siliceous hardpan at depths mostly less than 50 cm. This soil occurs on overland sheet wash plains and associated broad drainage tracts and among some gently undulating plains associated with areas of marginally higher relief. Soil textures range from loam to clay loam but are mostly sandy clay loam with few (<10%) if any, medium (2-6 mm) coarse fragments of quartz throughout and minor (<2%) accumulations of soft manganiferous segregations and slightly higher residual clay accumulations just above the hardpan. The soil has an earthy fabric and reaction is slightly acidic to neutral (field pH 5.5-7.5). These soils have hardsetting surfaces which are stabilised by moderate (10-50%) cryptogam crusts. Some have a protective light stony mantle. The hardpan and soil above are similarly coloured dark red to red (2.5YR 3/6 to 2.5YR 4/6). Some grade into shallow red earths (subgroup 5b).

Australian Soil Classifications: Duric Red Kandosols, Duric Orthic Tenosols, occasional Ferric-Duric Orthic Tenosols
Principal Profile Form: Um5.31, occasional Um1.43 or Gn2.12 intergrades
Erosion susceptibility: Moderately susceptible to sheet erosion and highly susceptible with removal of the cryptogam crust or extensive stony mantle. Where stony mantles exist susceptibility is low.

Shallow loam overlying red-brown hardpan

Representative profile

Soil type:	Shallow hardpan loam
Land system:	Woodline (site 277)
Land unit:	wide drainage line
Habitat:	*Drainage tract acacia shrubland* (DRAS)
Soil surface/condition:	firm to hardsetting with common (10-50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Duric Red Kandosol
Principal Profile Form:	Um5.31

Profile description

Depth (cm)	Horizon	Description
0-15	A11	Red (2.5YR 4/6) sandy clay loam (coarse sandy); massive structure; earthy fabric; partially slaking; non-dispersive; very firm consistence; slightly sticky; slightly plastic; non-calcareous; few (<2%), fine (<2 mm), subrounded quartz coarse fragments; field pH 6.0; gradual, smooth boundary.
16-45	A12	Red (2.5YR 3/6) sandy clay loam (fine sandy); massive structure; earthy fabric; partially slaking; non-dispersive; very firm consistence; slightly sticky; non-plastic; non-calcareous; few (2-10%), medium (2- 6 mm), subrounded quartz coarse fragments; field pH 7.0.
46+	D	Red-brown siliceous hardpan.

Group 6 – Loamy earths

6a) Deep red earths (83 sites) are uniform loamy textured or gradational, moderately deep to deep (>60 cm) soils often overlying red-brown siliceous hardpan. These soils occur on deeper margins of plains subjected to overland sheet flow and accumulation or sink zone areas such as vegetation groves, drainage foci and drainage lines. Where uniformly textured, the deep red earths are sandy clay loam throughout with residual clay and minor (<2%), fine (<2%), manganiferous accumulations immediately above the red-brown siliceous hardpan. Where gradational, the textures range from sandy loam in the upper horizons to clay loam in the subsoil. Except for a small proportion of gravelly subsoil deep red earths, most profiles contain few if any coarse fragments, and are weakly acidic to neutral (field pH 6.0-7.5). Surfaces are mostly stone-free, hardsetting with moderate (10-50%) cryptogam crusting except within vegetation groves, where the crust is replaced by leaf litter. Colours are dark red to red (2.5YR 3/6 to 2.5YR 4/6). Alkaline red earths occur on some loamy plains or within greenstone-based land systems. These soils usually overlie calcrete or contain calcareous nodules or gravels in the subsoil.

Australian Soil Classifications: Duric Red Kandosols, Red Kandosols, Duric Orthic Tenosols and minor Calcic Red Kandosols, Ferric-Duric Red Kandosols
Principal Profile Forms: Gn2.12, Gn2.11, Um5.31, Um5.32, Um5.52, Um5.42
Erosion susceptibility: Low to moderate under existing conditions but moderately susceptible to sheet erosion after soil surface crust removal

Representative profile

Soil type:	Deep red earth
Land system:	Yanganoo (site 433)
Land unit:	mulga grove
Habitat:	*Hardpan plain mulga grove* (GRMU)
Soil surface/condition:	hardsetting with abundant (>50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Red Kandosol
Principal Profile Form:	Gn2.11

Profile description

Depth (cm)	Horizon	Description
0-40	A	Dark red (2.5YR 3/6) sandy clay loam (medium sandy); massive structure; earthy fabric; completely slaking; non-dispersive; firm consistence; slightly sticky; slightly plastic; non-calcareous; few (2-10%), medium (2-6 mm), subrounded coarse fragments of quartz; field pH 5.5; abrupt, smooth boundary.
41-80	B1	Dark reddish brown (2.5YR 3/4) clay loam (medium sandy); massive structure; earthy fabric; firm consistence; slightly sticky; slightly plastic; non-calcareous; very few (<2%), fine (<2 mm), angular manganiferous coarse fragments; field pH 6.0, gradual smooth boundary.
81-100+	B2	Dark reddish brown (2.5YR 3/4) light clay; firm consistence; slightly sticky; slightly plastic; non-calcareous; very few (<2%), fine (<2 mm) angular manganiferous coarse fragments; very few (<2%), medium (2-6 mm), ferromanganiferous soft segregations: field pH 6.0.

6b) Deep calcareous loamy earths (1 site) are moderate to deep gradational soils with carbonates throughout the profile. They are found in calcareous sandplains, in sink

zones and low lying areas associated with calcreted drainage tracts. Surface textures range from sandy loams to sandy clay loams, grading to light clay. Coarse fragments of rounded calcrete nodules can vary is size from medium to coarse (2-20 mm) and in abundance from nil to 20%. Soft calcareous segregations and nodules vary from fine to medium (<2-6 mm) and become more abundant (>50%) with depth. Soil reaction is alkaline throughout (field pH 8.5-10.0). This soil often overlies a dense bed of calcareous nodules. Cryptogam crusting is moderate to abundant (10->50%). Soil colour ranges from reddish brown (2.5YR 3/6) to dark reddish brown (5YR 3/3) immediately below the surface to yellowish red (5YR 4/6) in the subsoil. This soil type is more common than sampling frequency suggests.

Australian Soil Classifications: Supracalcic and Calcic Calcarosols
Principal Profile Forms: Gc1.12, Gc1.21 or Gc1.22
Erosion susceptibility: Low to moderate – subject to sheet water and wind erosion where vegetation is depleted.

Group 7 – Shallow duplexes

7a) Shallow duplexes on granite (31 sites) normally less than 50 cm deep underlain by decomposing granite, with or without a stony mantle. It occurs on footslopes, alluvial plains, stony plains and adjacent to narrow drainages of granite-based land systems.

The surface soil is coarse-textured loamy sand, sandy loam or fine sandy loam. The subsoil has finer textures: sandy clay loam to light clay. The solum is generally massive structure throughout, only occasionally showing weak structure in the subsoil. Few or very few (<10%), medium (2-6 mm), coarse fragments of angular quartz occur in the topsoil, with few (2-10%), medium (2-6 mm), rounded ferruginous gravels occasionally in the subsoil. Colour is relatively uniform, being dark reddish brown (2.5YR 3/4) or dark red (2.5YR 3/6). Pebbles and cobbles (6-200 mm) of mostly granite and quartz dominate the surfaces which are hardsetting. The soil reaction trend is generally neutral (field pH 6.5-7.5) throughout, occasionally with alkaline (pH 8.0-9.5) subsoils.

Australian Soil Classifications: Red Chromosols, infrequent Brown Chromosols
Principal Profile Forms: Dr1.12, Dr1.15, Dr1.16, Dr1.52, Dr1.54, Dr1.55, Dr2.12, Dr2.51, Dr2.52, Dr2.53, Dr2.32, Dr2.72 with minor Dr4.52, Db0.12, Db0.52
Erosion susceptibility: Low if protected by abundant or moderate stony mantle, otherwise moderate to high depending on the condition of surface cryptogams; high susceptibility to gully erosion where tracks are inappropriately located or maintained.

Representative profile

Soil type:	Shallow duplex on granite
Land system:	Sherwood (site 434)
Land unit:	saline plain below breakaway footslope
Habitat:	*Plain mixed halophyte shrubland* (PHXS)
Soil surface/condition:	hardsetting with common (10-50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Red Chromosol
Principal Profile Form:	Dr1.54

Profile description

Depth (cm)	Horizon	Description
0-10	A	Red (2.5YR 4/6) clayey sand; single grain structure; sandy fabric; weak consistence; non-sticky; non-plastic; non-calcareous; very few (<2%), medium (2-6 mm), angular coarse fragments of quartz; field pH 7.0; sharp, smooth boundary.
11-40	B	Dark reddish brown (2.5YR 3/4) light clay; massive structure; earthy fabric; completely slaking non-dispersive; firm consistence; very sticky; very plastic; non-calcareous; very few (<2%), medium (2-6 mm), angular coarse fragments of quartz; very few (<2%), fine (<2 mm), soft manganiferous segregations; field pH 7.0.
41+	C	Weathered granite.

7b) Shallow duplexes on greenstone (12 sites) are mostly very shallow (10-40 cm) soils overlying decomposing metamorphic rock. They occur on plains below greenstone hills and ranges and occasionally amongst outcropping parent materials. Textures tend to be finer than granite-based equivalents. Topsoil horizons are mostly fine sandy loam overlying sandy clay loam or light to medium clay. Subsoils may have weak to moderate structure or are earthy and massive. Few to common (<2-20%), fine to coarse (<2-20 mm), angular and subangular inclusions of weathering parent material are common throughout the profile. Calcareous subsoils occur occasionally dependent on geology. Surfaces are mostly firm to hardsetting with occasional (<10%) rock outcrop and common stony mantles. Cryptogam crusting is moderate to abundant (10->50%). Soil reaction tend is neutral to alkaline (field pH 6.0-9.0). This soil is more common than sampling intensity suggests.

Australian Soil Classification: Red Chromosols
Principal Profile Forms: Dr2.12, Dr2.51, Dr2.52 and Dr2.53
Erosion susceptibility: Low to moderately susceptible to sheet erosion; moderate to high if cryptogam crust or stony mantle is disturbed.

Representative profile

Soil type:	Shallow duplex on greenstone
Land system:	Nallex (site 301)
Land unit:	low rise
Habitat:	*Stony plain bluebush mixed shrubland* (SBMS)

Soil surface/condition:	firm
Surface mantle:	common (10-20%) large pebbles (20-60 mm) of angular gabbro
Associated rock outcrop:	nil
Australian Soil Classification:	Red Chromosol
Principal Profile Form:	Dr2.52

Profile description

Depth (cm)	Horizon	Description
0-5	A	Dark reddish brown (2.5YR 2.5/4) fine sandy loam; massive structure; earthy fabric; non-slaking; non-dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; very few to few (<2-10%), fine to coarse (<2-20 mm), angular coarse fragments of weathered gabbro; field pH 6.5; abrupt, smooth boundary.
6-25	B	Dark reddish brown (2.5YR 2.5/4) sandy clay loam; massive structure; earthy fabric; partially slaking non-dispersive; loose consistence; slightly sticky; non-plastic; non-calcareous; very few (<2%), fine (<2 mm), angular coarse fragments of weathered gabbro; field pH 7.0.
26+	C	Weathered gabbro rock.

Overland water flow on shallow duplex soil

7c) Shallow duplexes on hardpan (47 sites) are shallow (<50 cm) soils occurring extensively on broad alluvial plains or adjacent to shallow duplexes on granite or greenstone (subgroups 7a and 7b). Topsoil textures range from loamy sand to sandy loam overlying a subsoil of clay loam or light clay. This may be pedal or massive. Few (2-10%), medium (2-6 mm) coarse fragments of quartz occur throughout the topsoil and very few (<2%), fine (<2 mm), manganiferous segregations occur in the lower subsoil especially immediately above the siliceous red-brown hardpan. Soil reaction is commonly weakly acidic to mildly alkaline (field pH 6.5-8.0), with some types having alkaline (field pH 8.0-9.0) subsoil where influenced by calcrete. Surfaces are hardsetting or occasionally crusted, both often dominated by moderate to heavy (10->50%) cryptogams. These soils do not generally have a stony mantle. Colour is mainly dark reddish brown to dark red (2.5YR 3/3 to 2.5YR 3/6) throughout.

Australian Soil Classification: Duric Red Chromosol
Principal Profile Forms: Dr1.15, Dr1.16, Dr1.52, Dr1.54, Dr1.55, Dr2.12, Dr2.13, Dr2.52, Dr2.52, Dr2.53 and Dr2.72
Erosion susceptibility: High following vegetation removal or initial soil surface decline through sheet erosion, otherwise moderate

Representative profile

Soil type:	Shallow duplex on hardpan
Land system:	Carnegie (site 41)
Land unit:	alluvial plain on hardpan
Habitat:	*Bladder saltbush low shrubland* (BLSS)
Soil surface/condition:	hardsetting with abundant (>50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Duric Red Chromosol
Principal Profile Form:	Dr1.15

Profile description

Depth (cm)	Horizon	Description
0-10	A	Red (2.5YR 4/6) loamy sand; sandy fabric; partially slaking; partially dispersive; very weak consistence; non-sticky; non-plastic; non-calcareous; no coarse fragments; field pH 7.0; abrupt, smooth boundary.
11-20	B	Dark red (2.5YR 3/6) sandy clay loam; moderately pedal structure; non-slaking non-dispersive; weak consistence; non-sticky; non-plastic; non-calcareous; no coarse fragments; field pH 7.0.
21+	D	Siliceous red-brown hardpan.

Group 8 – Deep duplexes

Deep sandy duplex soils (37 sites), are primarily deeper than 80 cm and occur on broad alluvial plains often associated with major drainage tracts or lake margins. They often overlie calcrete, red-brown siliceous hardpan or very occasionally decomposing greenstones. Topsoils range from loamy sand to fine sandy loam and subsoil textures from clay loam to medium clay and may overlie gypsum at depth. Topsoil structure is mostly massive while the subsoil ranges from massive to highly structured showing rough or smooth-faced peds. Coarse fragments are restricted to few (2-10%), medium (2-6 mm), angular fragments of quartz in the topsoil, with very few (<2%), fine (<2 mm) quartz fragments in the subsoil. Soft fine (<2 mm), manganiferous segregations occur minimally in some upper subsoils. Deep soils occurring beside salt lakes, large playas or at major drainage tracts may contain calcareous segregations or gypsum at depth. Soil reaction is neutral to alkaline (field pH 6.5-8.5) within the topsoil and highly alkaline (field pH >8.0.-10.0) in the subsoil. Sporadically bleached A2 horizons occur very occasionally. Colour is red throughout (2.5YR 3/6 to 2.5YR 5/6), although occasionally some seasonally wet deep subsoils show weak mottling. Surfaces are mostly stone-free, have moderate to heavy (>50%) cryptogams and are hardsetting or crusted.

Some soils have soft, non-hardsetting surfaces. These occur on loamy plains or sand sheets in conjunction with sandy-surfaced red earths (group 4) and deep red sands (subgroup 3c). These soils have deep (>50 cm) upper horizons of loamy or clayey sand and overlie deep (>100 cm) subsoils of sandy clay loam and sandy clay. These soils have sandy or single grain structure with few (2-10%), medium (2-6 mm),angular coarse fragments of quartz and may overlie ferruginous gravel or calcrete. Field pH is generally weakly acid to alkaline (pH -6.5-9.0) dependent on the nature of underlying substrate. The surface is soft to firm ,with much coarse wind blown sand. Colour is yellowish red (5YR 5/6) in the topsoil to red (2.5YR 4/8) in the subsoil.

Australian Soil Classifications: Red Chromosols, Duric Red Chromosols, Duric Red Dermosols, Duric Red Sodosols
Principal Profile Form: Dr1.12, Dr1.13, Dr1.51, Dr1.53, Dr2.12, Dr2.13, Dr2.51, Dr2.53, Dr2.83, Dr3.42, Dr4.12, Dr4.13, Dr4.51 and Dr4.53
Erosion susceptibility: Highly susceptible to water and wind erosion after initial soil surface decline or vegetation removal, otherwise moderate.

Group 9 – Non-cracking clays

9a) Shallow clays (32 sites) occur in depositional areas within drainage or sink zones, lake margins, stony and saline plains, and within pockets of greenstone hill systems. Where underlain by hardpan, shallow clays often occur as pockets within alluvial (mainly duplex) plains or within drainage foci. Textures are generally light clay, increasing marginally with depth, with little or no coarse fragments or calcareous nodules. Subsoils may be earthy, massive or weakly pedal. Some soils exhibit light and sporadic leaching below the dominant surface horizon. Soil depth is shallow (20-50 cm). Surfaces are moderately to strongly cryptogamic (10-70%) and are hardsetting. Soil reaction is neutral (field pH 6.5-8.0). Where underlain by calcrete the clays tend to have an alkaline soil reaction trend (field pH 7.0-9.5). These soils occur within some greenstone ranges or as isolated pockets within lake margins. Colour varies from dark red (2.5YR 3/6) to yellowish red (5YR 4/6).

Australian Soil Classifications: Duric Red Kandosols and Dermosols, Petrocalcic Red Kandosols, minor Hypercalcic Calcarosols
Principal Profile Form: Uf5.12, Uf6.12, Uf6.21, Uf6.31 and Uf6.71
Erosion susceptibility: Highly susceptible to sheet erosion after excessive plant removal or continued soil crust decline; low susceptibility in drainage foci

Representative profile

Soil type:	Shallow clay (on hardpan)
Land system:	Carnegie (site 423)
Land unit:	narrow drainage line
Habitat:	*Drainage tract acacia shrubland* (DRAS)
Soil surface/condition:	hardsetting with abundant (>50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Duric Red Kandosol
Principal Profile Form:	Uf6.71

Profile description

Depth (cm)	Horizon	Description
0-50	A	Dark red (2.5YR 3/6) light-medium clay; massive structure; earthy fabric; completely slaking; non-dispersive; firm consistence; very sticky; very plastic; non-calcareous; no coarse fragments; field pH 7.0.
51+	D	Siliceous red-brown hardpan.

9b) Deep clays (34 sites) are uniform fine-textured, moderately deep to deep (>80 cm) soils occurring on open flood plains, alluvial plains, claypans and drainage foci. Textures range from clay loam and light clay at the surface to light and heavy clay in the deep subsoil. These soils often overlie siliceous red-brown hardpan or calcrete. Consistence is firm to strong, structure ranges from massive to strongly pedal. Carbonates occur occasionally in some subsoils as soft segregations or nodules. Few, if any coarse fragments occur. Adjacent to lake beds or large playas gypsum is common in the subsoil. Colour ranges from dark reddish brown (2.5YR 3/6) and dark red (2.5YR 4/6) in the topsoil to red (2.5YR 4/6) and yellowish red (10R 5/6 and 5YR 4/6) in the subsoil. The soil surfaces are mainly hardsetting with cryptogam crusting common to abundant (10->50%), except in claypans. Some surfaces are loose and partly self-mulching, a characteristic of cracking clays (subgroup 10), and they are generally stone-free. Where clay is underlain by hardpan, occasional weak mottling is evident in the lower subsoil. Soil reaction is neutral to highly alkaline (pH 7.0-9.5).

Australian Soil Classifications: Red Kandosols and Dermosols, Hypercalcic, Hypocalcic and Duric Red Kandosols, minor Calcic Calcarosols, Lithocalcic Calcarosols and Red Sodosols
Principal Profile Forms: Uf5.12, Uf6, Uf6.12, Uf6.13 Uf6.21, Uf6.31, Uf6.34 and Uf6.71
Erosion susceptibility: Highly susceptible to sheet erosion after plant removal or soil surface decline, otherwise moderate

Representative profile

Soil type:	Deep clay
Land system:	Mileura (site 322)
Land unit:	saline plain
Habitat:	*Samphire flat* (SAMP)
Soil surface/condition:	hardsetting with abundant (>50%) cryptogam crusting
Surface mantle:	nil
Associated rock outcrop:	nil
Australian Soil Classification:	Pedal Hypocalcic Calcarosol
Principal Profile Form:	Uf6.31

Profile description

Depth (cm)	Horizon	Description
0-1	A11	Reddish brown (5YR 4/4) medium clay; strongly pedal structure; completely slaking; non-dispersive; strong consistence; very sticky; very plastic; highly calcareous; no coarse fragments; field pH 10.0; sharp, smooth boundary.
2-4	A12	Yellowish red (5YR 4/6) medium clay; strongly pedal structure; completely slaking non-dispersive; firm consistence; very sticky; very plastic; highly calcareous; no coarse fragments; field pH 10.0; abrupt smooth boundary.
5-30	B21	Yellowish red (5YR 4/6) light clay; strongly pedal structure; completely slaking non-dispersive; weak consistence; very sticky; very plastic; highly calcareous; few (2-10%), rounded, coarse fragments of calcrete; field pH 10.0; abrupt smooth boundary.
31-80+	B22	Red (2.5YR 4/6) light clay; strongly pedal structure; completely slaking partially dispersive; very weak consistence; very sticky; very plastic; highly calcareous; no coarse fragments; field pH 10.0.

Group 10 – Cracking clays

Cracking clays (9 sites) are uniform fine-textured, deep (>100 cm) soils showing seasonal surface cracking, occurring in open clay plains and drainage foci. Surface textures are light clay overlying subsoil textures of medium and heavy clay. Few (<2-20%) fine (<2 mm) soft calcareous segregations and gypsum crystals often occur in the subsoil. Structure below the topsoil is strongly pedal (rough and smooth peds), and soil reaction is alkaline (field pH 7.0-9.0). The surface is self-mulching or exhibits large cracks when dry. Cryptogamic crusting is minimal. Colour ranges from dark reddish brown (2.5YR 3/3 and 5YR 3/4) to red (2.5YR 4/8). Some show weak to moderate surface cracking or self-mulching and have been included.

Australian Soil Classifications: Self-mulching or Massive Red Vertosols, infrequent Red Dermosols.
Principal Profile Form: Ug5.38, Ug6.3, minor Uf6.21
Erosion susceptibility: Moderately to highly susceptible to structural decline and subsequent soil surface sealing after vegetation depletion

Representative profile

Soil type:	Cracking clay
Land system:	Merbla (site 682)
Land unit:	gilgai plain
Habitat:	*Gilgai grassy low shrubland* (GGLS)
Soil surface/condition:	self-mulching
Surface mantle:	very minor (<2%) subangular mixed gabbro
Associated rock outcrop:	nil
Australian Soil Classification:	Self-mulching Red Vertosol
Principal Profile Form:	Ug5.38

Profile description

Depth (cm)	Horizon	Description
0-3	A	Dark reddish brown (2.5YR 3/4) light clay; weakly pedal structure; completely slaking; partially dispersive; very weak consistence; very sticky; very plastic; non-calcareous; few to common (2-20%), fine to coarse (2-20 mm), rounded ferromanganiferous coarse fragments; field pH 9.0; abrupt, smooth boundary.
4-15	B21	Dark reddish brown (2.5YR 3/4) medium clay; strongly pedal structure; completely slaking; partially dispersive; very firm consistence; very sticky; very plastic; non-calcareous; few to common (2-20%), fine to coarse (2-20 mm) rounded ferromanganiferous coarse fragments; field pH 9.0; clear, smooth boundary.
16-40	B22	Dark red (2.5YR 3/6) medium-heavy clay; strongly pedal structure; completely slaking partially dispersive; strong consistence; very sticky; very plastic; non-calcareous; no coarse fragments; field pH 9.0; gradual boundary.

41-100+	B23	Dark red (2.5YR 3/6) heavy clay; strongly pedal structure; strong consistence; very sticky; very plastic; non-calcareous; no coarse fragments; field pH 9.0.

Group 11 – Salt lake soils

Highly saline soils (3 sites) occur in lake beds, on gypseous plains, some drainage flats and at terminated drainages. They are highly saline, stone-free and very shallow (often <30 cm). Textures range from clayey sands to clay loams often overlying gypsum or cemented carbonates. Colour ranges from strong brown (7.5YR 4/6) to dark red (2.5YR 3/6). Some surfaces are crusted with salt, showing polygonal cracking or exhibit a soft, loose, powdery surface horizon with visible salt crystals. With high salinity and susceptibility to prolonged waterlogging, these soils support little or no vegetation. Away from lake beds, the less saline lake margins support salt tolerant vegetation such as samphire and saltbush.

Australian Soil Classifications: Gypsic and Haplic Hypersalic Hydrosols, some Red Sodosols
Principal Profile Form: Dr1, Dr4 and Uf1
Erosion susceptibility: Nil

Gypseous sediments which occur in gypseous muds on lake beds or are pure gypsum (calcium sulphate) dunes which are formed adjacent to some major lake beds have been incorporated into this group. The dunes may be up to 5 m high. They have a crusted uneven surface with a white (10YR 8/2) to yellow (10YR 7/6) colour.

Australian Soil Classification: Hypergypsic Rudosols
Principal Profile Form: not applicable

Group 12 – Other soils

Juvenile or alluvial soils (22 sites) are undifferentiated soils formed from recent alluvium that are so juvenile that true soil formation processes are not expressed in the disorganised profiles. They occur in, or immediately adjacent to, major and minor rivers or flow lines. These sediments may have many layers of coarse loose sand, clayey sand, silty sand and silty clay. Layers containing river pebbles are often visible on exposed creek banks. Depth is variable, but where it is less than 1 m, the soil is often underlain by rock or hardpan which, within drainage lines, may have a thin calcrete veneer. Fluvial sediments are often found on levee banks associated with the larger flow lines. They may be no more than poorly sorted coarse sands, depending on catchment size and lithology. Catchments with metamorphic lithology tend to produce finer sediments than granitic-based catchments where quartz sand predominates. These soils also occur in lake beds, drainage foci or other low lying areas receiving major run-on. At drainage channels they are mostly weakly acidic to neutral (field pH 6.0-7.5) and are non-saline, but saline forms occur in localised areas close to or within lake margins. Soil colour varies from dark red (2.5YR 3/6) to strong brown (5YR 5/6).

Australian Soil Classifications: Stratic Rudosols (creek systems), Hypergypsic or Hypersalic Rudosols (lake beds and large saline playas)
Principal Profile Form: not applicable
Erosion susceptibility: River channels – mobile river sediments; levee banks – mostly stable under vegetation; lake beds and drainage foci – low

Soil distribution

Specific soil types often occur in particular zones of the landscape. Table 2 shows the dominant and associated soils on a land system basis and Table 3 shows the soils on a land unit level.

Stony soils (group 1), shallow red earths (5c) associated with greenstone hills and ridges, and shallow coarse red clayey sands (2a) associated with granitic hills, plains and breakaways, occur widely throughout the survey area. Sandplains adjoining breakaway backslopes or as extensive sheets in central and eastern parts of the survey have predominantly deep red clayey sands (3a) or deep red sands on occasional dunes.

Immediately below breakaways and some granite outcrops, colluvial slopes have shallow duplex soils on granite (7a) and further downslope shallow duplexes on hardpan (7c).

Downslope of the duplex soils, gently sloping plains support shallow loams (frequently with stony mantles), often overlying granite (and less commonly greenstone) or hardpan in the lower reaches. These peneplains give way to nearly level broad plains carrying sheet flow toward drainage tracts and lake systems. These sheet flood (hardpan) plains with shallow hardpan loams (5d) and shallow red earths (5c) are very extensive and widely distributed.

Deep accumulations of sand occur intermittently on some hardpan plains as banks of soil (wanderrie banks). These soils are deep red clayey sands (3a).

Red earths occur on broad loamy plains and some drainage tracts. Most soils are deep red earths (6a) and sandy-surfaced red earths (4) with minor deep calcareous loamy earths (6b). These soils are transitional between sheet flood alluvial plains and sandplains.

The dominant soils on drainage tracts are shallow hardpan loams (5d), deep red earths (6a), less frequently shallow calcareous loams (5a) and shallow red clayey sands on calcrete (2c) and duplex soils (7c, 8).

Drainage tracts terminating at drainage foci or claypans have deep red earth (6a) or clay (9b) soils. Saline alluvial plains adjacent to lake bed soils have duplex soils (7, 8) and occasional sand dunes (deep red sands – 3c). Lake beds support many different soil types, but most are grouped as highly saline soils (11).

A map showing the broad distribution of the major soil types in the survey area is available from Agriculture Western Australia. Soil types have been amalgamated to produce a generalised map ; the mapping units are mostly a combination of the 25 soil types described in this report. The broad group of **Red shallow sand** includes shallow coarse red clayey sand (2a), shallow red clayey sand with ferruginous gravel (2b), shallow red clayey sand on calcrete (2c), shallow red clayey sand (2d), and shallow yellow clayey sand (2e). **Red deep sand** is a combination of red deep clayey sand (3a), red deep sand (3c) and sandy-surfaced red earth (4) soil types. The broad mapping group of **Red loam** includes shallow stony red earth (5b), shallow red earth (5c), shallow hardpan loam (5d) and deep red earth (6a). The broad group of **Duplex soil** includes all types regardless of depth or substrate. They are shallow duplex on granite (7a); shallow duplex on greenstone (7b); shallow duplex on hardpan (7c) and deep duplex (8). Similarly the **Calcareous loam** broad grouping is a combination of shallow calcareous

Table 2. Dominant and minor soils within land systems

Soil type	Land systems where specified soil type is dominant/co-dominant	Land systems where specified soil type is minor
Stony soils (1)	Brooking, Dryandra, Gabanintha, Lawrence, Naluthanna, Teutonic	Bevon, Hootanui, Narryer, Singleton, Violet, Watson
Shallow coarse red clayey sands (2a)	Bandy, Challenge, Nerramyne, Norie*, Olympic, Sherwood	Dryandra, Hootanui, Waguin, Watson, Windarra
Shallow red clayey sands with ferruginous gravel (2b)		Dryandra, Graves, Narryer, Nubev
Shallow red clayey sands on calcrete (2c)	Cosmo	Cunyu
Shallow red clayey sands (2d)	Euchre, Joy, Narryer	Deadman, Doney, Gransal, Graves, Illaara, Marmion, Moriarty, Nubev, Wilson, Yarrameedie
Shallow yellow clayey sands (2e)		Bandy, Joseph, Marmion, Skipper
Deep red clayey sands (3a)	Bannar, Bullimore, Bunny, Desdemona, Kalli, Marmion, Tyrrell, Yowie	Ararak, Campsite, Carnegie, Cosmo, Joseph, Melaleuca, Pindar, Waguin
Deep yellow clayey sands (3b)	Joseph	Euchre
Deep red sands (3c)		Bullimore, Kalli
Sandy-surfaced red earths (4)	Melaleuca	Bullimore, Monk, Yanganoo
Shallow calcareous loams (5a)	Bevon, Cunyu, Graves, Mileura	Deadman, Nallex, Naluthanna, Racecourse
Shallow stony red earths (5b)	Lawrence, Mulline, Tallering, Yarrameedie	Brooking, Gabanintha, Moriarty
Shallow red earths (5c)	Brooking, Doney, Felix, Illaara, Monk, Moriarty, Nubev, Rainbow, Tango, Violet, Watson, Windarra, Yalluwin	Bandy, Bannar, Euchre, Gabanintha, Graves, Hamilton, Jundee, Lawrence, Nerramyne, Norie, Pindar, Ranch, Roderick, Sherwood, Singleton, Tealtoo, Teutonic, Wilson, Wiluna, Yilgangi
Shallow hardpan loams (5d)	Austin, Hamilton, Jundee, Marlow, Monitor, Ranch, Yanganoo	Ararak, Bunny, Doney, Ero, Monk, Tealtoo, Tindalarra, Watson, Wiluna, Yalluwin, Yowie
Deep red earths (6a)	Ararak, Campsite, Desdemona, Pindar, Rainbow, Tindalarra, Woodline	Bannar, Jundee, Merbla, Monk, Yanganoo, Yowie
Deep calcareous loamy earths (6b)	Deadman, Tealtoo	Doney, Felix, Olympic, Tango
Shallow duplexes on granite (7a)	Gransal, Gumbreak, Joy, Waguin, Wiluna	Euchre, Narryer, Sherwood
Shallow duplexes on greenstone (7b)	Hootanui, Nallex, Singleton, Steer, Yilgangi	Gabanintha, Mulline, Naluthanna, Nubev
Shallow duplexes on hardpan (7c)	Ero, Roderick, Wilson, Yewin	Carnegie, Mileura, Monitor
Deep sandy duplexes (8)	Racecourse, Skipper	Merbla, Roderick, Steer
Shallow clays (9a)		Marlow, Mileura, Monitor, Yewin
Deep clays (9b)	Campsite	Mileura, Moriarty, Racecourse, Steer, Yalluwin
Cracking clays (10)	Merbla	
Highly saline soils (11)	Carnegie	Skipper, Yewin
Juvenile soils (12)		Carnegie, Nallex, Skipper, Wilson

* bare rock has been included in group 2a.

loam (51 and deep calcareous loamy earth (6b). All **Clay** soils are mapped as one unit and consist of shallow clay (9a), deep clay (9b) and cracking clay (10). The other broad mapping groups are the same as the soil types, **Stony soil, Yellow deep sand,** and **Salt lake soil.**

Red sandplains dominate the Sandstone and Youanmi map sheets while yellow sandplain is dominant on the Yalgoo, and Perenjori sheets, and common on the Ninghan and Barlee sheets. Salt lake soil dominates or is common on the Barlee, Youanmi, Ninghan and Kirkalocka map sheets. Stony soils are generally small and restricted to hill belts or ranges that occur sporadically through the area. Calcareous and clay soils are not common and generally occur only as isolated pockets.

Soil and land qualities

The unmapped land units within the land systems have unique properties such as slope, topsoil texture, amount of vegetative cover and surface mantle, which affect land use. Land capability is the ability of the land to support a particular land use, without permanent damage (Wells and King 1989). It is determined by considering a combination of the land unit's inherent properties ('land qualities') and the specific land use.

Table 3 presents ratings for four land qualities: water erosion risk, wind erosion risk, flooding risk and inundation risk. The classes, based on Wells and King 1989, are defined below. Many other land qualities can be applied to the land units in the survey area according to what land use is being considered. For example, land qualities such as soil workability, topsoil nutrient retention ability and moisture availability would need to be determined and assessed for horticultural use.

The survey area supports mostly pastoral activities, with minor components of mining, tourism, horticulture and conservation. The ratios of land use may alter slightly in the future, but the types of land use will most likely remain largely the same. Table 3 provides pastoral potential for each soil type based on the pastoral value of the vegetation (habitat) it supports.

Water erosion risk

Water erosion risk is defined as the susceptibility of a parcel of land to erosion caused by water. Water erosion is a process in which soil is detached from the land and transported by the action of rainfall, run-off or seepage. The most common types are sheet, gully, rill and streambank erosion. The following classes describe water erosion risk.

Risk class	*Likely situation*
High	Very gentle slopes (<3%) within major drainage tracts subject to a high flood hazard Without stony mantles on gentle slopes (>3%) Within or adjacent to defined drainage channels
Moderate	Very gentle slopes (<3%) within major drainage tracts subject to a moderate flood hazard Stony mantles on moderate slopes (>10%) Level plains (<1%) without stony mantles within zones subject to a moderate flood hazard
Low	Nearly level plains (<1%) within zones subject to a low flood hazard With stony mantles on gentle slopes (<3%) With stony mantles and/or common (10-50%) outcrop on moderate slopes (>10%) With soft or loose surfaces within zones subject to a low flood hazard
Nil	Within zones subject to no flood hazard With uniform coarse textures and firm and/or hardsetting surfaces on level plains (<1%) With stony mantles and abundant outcrop (>50%) on moderate slopes (>10%) Soils located in sink or accumulation zones (e.g. lakes, playas and claypans)

This sheep pad has caused surface crust decline and channelised flow on an area subject to sheet wash and has started erosion

Table 3. Land type and land unit, soil types, habitats and susceptibility ratings

Land type and land units	Soil type	Dominant habitat	Pastoral potential	WiE[1]	WaE[2]	FL[3]	IN[4]
Hills, ridges and plateaux							
Hillslopes, ridges and crests	Stony soils (1)	SIMS, GHAS, SIAS	Very low to Low	L	L	N	N
	Shallow calcareous loams (5a)	GHAS	Low	L	L	N	N
	Shallow stony red earths (5b)	SIAS, SIMS	Very low to Low	L	L	N	N
	Shallow red earths (5c)	SIAS, SIMS, GHMW	Very low to Low	L	L	N	N
	Shallow duplexes on greenstone (7b)	SIMS	Low	L	L	N	N
Low rises	Stony soils (1)	SIAS, GHAS	Low	L	L	L	N
	Shallow coarse red clayey sands (2a)	SGRS	Moderate	L	L	L	N
	Shallow red clayey sands with ferruginous gravel (2b)	LACS	Very low	L	L	L	L
	Shallow red clayey sands (2d)	SGRS	Moderate	L	L	L	N
	Shallow calcareous loams (5a)	SIAS	Very low	L	L	L	N
	Shallow stony red earths (5b)	SIMS	Low	L	L	L	N
	Shallow red earths (5c)	GHAS	Low	L	L	L	N
Breakaway or hill plateaux	Stony soils (1)	BRXS	Low	L	N	N	N
	Shallow coarse red clayey sands (2a)	BRXS	Very low to Low	L	L	N	N
	Shallow red clayey sands with ferruginous gravel (2b)	BRXS, SIAS	Low	L	L	L	L
Stripped surfaces	Stony soils (1)	BRXS	Low	L	L	L	L
	Shallow coarse red clayey sands (2a)	BRXS	Low	M	L	L	N
	Shallow red clayey sand with ferruginous gravels (2b)	GABS	Moderate	L	L	L	L
Breakaway footslopes	Stony soils (1)	PYAW	Moderate	L	L	L	L
	Shallow red earths (5c)	BCLS	High	L	M-H	L	N
	Shallow duplexes on granite (7a)	BCLS, PYAW	Moderate to High	L	M-H	L	N
Hill footslopes	Shallow stony red earths (5b)	SAES	Moderate	L	L-M	L	N
	Shallow red earths (5c)	BCLS, BECW, GHAS, SIAS	Very low to High	L	M	L	N
Stony and loamy plains							
Gritty-surfaced plains	Shallow coarse red clayey sands (2a)	GABS, GMAS	Moderate	L	L	N	L
	Shallow red clayey sands (2d)	GABS, SGRS	Moderate	L	L	L	L
	Shallow stony red earths (5b)	SGRS, SIAS	Very low to Moderate	L	L	L	L
	Shallow red earths (5c)	SGRS	Moderate	L	L	L	L
	Shallow duplexes on granite (7a)	SBMS	Moderately high	L	M-H	L	L
Lateritic plains	Shallow red clayey sands with ferruginous gravel (2b)	SACS, LACS	Very low	L	L	N	N
	Shallow red earths (5c)	MUBW, HCAS, PYAW, SACS	Very low to Moderate	L	L	N	N
	Shallow hardpan loams (5d)	GRMU, PYAW	Moderate to Moderately high	L	L	N	N
	Deep red earths (6b)	LACS, MUBW	Very low to Moderate	L	L	L	L
Stony plains	Stony soils (1)	SIMS	Low	L	L	L	L
	Shallow coarse red clayey sands (2a)	SAES	Moderate	L	L	L	L
	Shallow red clayey sands with ferruginous gravel (2b)	LACS, SIAS	Very low	L	L	L	N
	Shallow red clayey sand (2d)	GABS	Moderate	L	L	L	L
	Shallow stony red earths (5b)	SMBS, HMCS, SAES	Moderate to Moderately high	L	L-M	L	L
	Shallow red earths (5c)	HPMS, SIAS, SIMS	Low to Moderate	L	L	L	L
	Shallow hardpan loams (5d)	SAES, SBMS	Moderate to Moderately high	L	L	L	N
	Shallow duplexes on granite (7a)	SBMS, SGRS	Moderate to Moderately high	L	L-M	L	L
	Shallow duplexes on greenstone (7b)	SBMS, SAES	Moderate to Moderately high	L	L-M	L	L
	Shallow duplexes on hardpan (7c)	SBMS	Moderately high	L	L-M	L	L

Table 3. continued . . .

Land type and land units	Soil type	Dominant habitat	Pastoral potential	WiE[1]	WaE[2]	FL[3]	IN[4]
Loamy plains	Sandy-surfaced red earths (4)	MAAS, MUWA, PLMS, SWGS	Very low to Moderate	L	L-M	L	L
	Shallow calcareous loams (5a)	PECW	High	L	L-M	L	L
	Shallow red earths (5c)	HCAS, SAES	Moderate	L	L-M	L	L
	Shallow hardpan loams (5d)	HPMS, HCAS, HMCS, MUBW	Moderate to Moderately high	L	L-M	L-M	L
	Deep red earths (6a)	PYAW, MUBW, HCAS, HPMS	Moderate	L	L-M	L-M	L
	Shallow duplexes on hardpan (7c)	HPMS, HCAS, HMCS	Moderate to Moderately high	L	M-H	L-M	L
Calcrete plains and platforms	Shallow red clayey sands on calcrete (2c)	JAMS, CAPW	Moderate to moderately high	L-M	M-H	M-H	M-H
	Shallow red clayey sands (2d)	JAMS, SSAS	Moderate to High	L-M	L	M	M
	Shallow calcareous loams (5a)	JAMS, CAPW, PYAW	Moderately high to High	L-M	M-H	M-H	M
	Shallow red earths (5c)	GHMW, JAMS	Low to moderate	L-M	L-M	L	L
Sandplains and banks							
Shallow sand sheets	Shallow red clayey sands with ferruginous gravel (2b)	LSHE, SCMS, SWGS, SASP	Very low to Low	L-M	L	N	N
	Shallow red clayey sands (2d)	MUBW, SACS	Very low to Moderate	L	L	L	L
Sand sheets with ironstone gravels	Shallow yellow clayey sands (2e)	SASP, SCMS	Very low	L	L	N	N
	Deep red clayey sands (3a)	SCMS, SASP	Very low	L	L	L	L
	Deep yellow clayey sands (3b)	SCMS	Very low	L-M	N	N	N
Sand banks	Deep red clayey sands (3a)	WABS, SACS, SBLS	Very low to Moderately high	L-M	N	N	N
Sandplains dunes and swales	Deep red clayey sands (3a)	MAAS, SASP, SDSH, SWGS	Very low to Low	L-M	N	N	N
	Deep red sands (3c)	SASP, SDSH	Very low	L-M	N	N	N
	Sandy-surfaced red earths (4)	SAMU, SASP	Very low	L	L	L	L
Sandy-surfaced plains	Deep red clayey sands (3a)	SASP	Very low	L-M	N	N	N
Alluvial plains, drainage zones and lakes							
Alluvial plains	Shallow red clayey sands (2d)	ASWS, PHXS, PYCW	High	L	M-H	L	L
	Deep red clayey sands (3a)	SSAS	High	L	L	L	L
	Shallow red earths (5a)	PYCW, BLSS, PECW	High	L	L-M	L-M	L
	Shallow hardpan loams (5d)	ASWS, PSAS, PYAW, SSAS	Moderate to High	L	L-M	L-M	L
	Deep red earths (6a)	PECW, PYAW	High	L	L	L	L
	Shallow duplexes on granite (7a)	PSAS, PECW, USBS, ASWS	Moderately high to High	L	H	L	L
	Shallow duplexes on greenstone (7b)	PSAS	High	L	H	L	L
	Shallow duplexes on hardpan (7c)	PSAS, ASWS, BLSS, PXHS	High	L	H	L-M	L-M
	Deep sandy duplexes (8)	PSAS, PXHS, SAMP	Moderate to High	L	H	M-H	M-H
	Shallow clays (9a)	BLSS, JAMS, PXHS, SSAS	Moderate to High	L	M-H	M-H	M-H
	Deep clays (9b)	PECW, PSAS, PXHS	High	L	H	M-H	M-H
Saline plains	Shallow hardpan loams (5d)	PYCW	High	L	L-M	M	M
	Shallow duplexes on greenstone (7b)	PECW	High	L	M-H		
	Deep sandy duplexes (8)	ASWS,PSAS, SAMP	Moderate to High	L	HL-M	M-H	M-H
	Shallow clays (9a)	FRAN, PECW	Moderate to High	L	M-H	L-M	L-M
	Deep clays (9b)	PSAS, PXHS, SAMP	Moderate to High	L	M-H	M-H	M-H
Claypans	Deep clays (9b)	ACGU	Moderate	N	L	M-H	M-H
Gilgai plains	Deep clays (9b)	SAMP	Moderate	N	L-M	M-H	L-M
	Cracking clays (10)	GGLS	Very high	N	M-H	M-H	L-M

Table 3. continued . . .

Land type and land units	Soil type	Dominant habitat	Pastoral potential	WiE[1]	WaE[2]	FL[3]	IN[4]
Narrow drainage tracts	Shallow red coarse clayey sands (2a)	DRAS, UFTH	Very low to Moderate	L	M	M	M
	Shallow red clayey sands (2d)	BCLS, CBKW, DRAS, SSAS	Moderate to High	L	L-M	M	M
	Shallow red earths (5c)	DACS, DRAS, PSAS	Moderate to High	L	L-M	L-M	L
	Shallow hardpan loams (5d)	DRAS	Moderate	L	L-M	L-M	L
	Deep red earths (6a)	DRAS	Moderate	L	L	L	L
	Shallow duplexes on granite (7a)	CBKW, DRAS, HMCS, PYCW	Moderate to High	L	H	L-M	L-M
	Shallow duplexes on hardpan (7c)	DRAS, PSAS	Moderate to High	L	H	L-M	L-M
	Shallow clays (9a)	DRAS	Moderate	L	M-H	M-H	M-H
	Juvenile soils (12)	DRAS	Moderate	L	H	H	H
Broad drainage tracts	Shallow hardpan loams (5d)	DRAS, HPMS	Moderate	L	L-M	L-M	L
	Deep red earths (6b)	DRAS, HPMS	Moderate	L	M-H	L	L
	Shallow clays (9a)	DRAS, ACGU	Moderate	L	M-H	M-H	M-H
	Deep clays (9b)	DRAS, PSAS, SSAS	Moderate to High	L	M-H	M-H	M-H
	Juvenile soils (12)	PSAS	High	L	H	H	H
Incised drainage channels and levees	Juvenile soils (12)	CBBS, CBKW, DACS, DRAS	Low-high	M	H	M-H	M-H
Drainage foci or groves	Shallow hardpan loams (5d)	GRMU, HPMS,ACGU	Moderate to Moderately high	N	L	L-M	L
	Deep red earths (6b)	GRMU, ACGU, DRAS, PECW	Very low to High	L	M-H	L	L
	Shallow duplexes on hardpan (7c)	DRAS	Moderate	L	M-H	M	M
	Deep sandy duplexes (8)	PYCW, UFTH	High	L	M-H	M	M
	Deep clay (9b)	ACGU, PDFT, DACS, DRAS	Moderate to High	N	L	M-H	M-H
Swamps	Deep sandy duplexes (8)	MESS	Very low	L	L	H	H
	Shallow clays (9a)	MESS, PDFT	Very low to Moderate	L	L	H	H
Lake margins	Shallow red clayey sands (2d)	SAMP	Moderate	L	L	L-M	L-M
	Shallow duplexes on hardpan (5d)	PSAS, PXHS, ASWS	High	L	M-H	M	M
	Deep duplexes (8)	PSAS, PXHS, SAMP	Moderate to High	L	M-H	H	M
	Shallow clays (9a)	SAMP	Moderate	L	L	H	H
	Kopi dunes (11)	KOPI	Low	M-H	N	N	N
Lake beds	Highly saline soils (11)	No vegetation	Nil	N	N	H	H
	Juvenile soils (12)	No vegetation	Nil	N	N	H	H

WiE[1] = Wind erosion risk
WaE[2] = Water erosion risk
FL[3] = Flooding risk
IN[4] = Inundation risk
where N= Nil; L= Low; M= Moderate and H= High.
Habitat codes: see ecological assessment chapter

Wind erosion risk

Wind erosion risk is defined as the susceptibility of a parcel of land to erosion caused by wind. Wind erosion is a process in which soil is detached and transported by wind. Transport of wind-blown particles occurs by surface creep, suspension or saltation. The following classes describe wind erosion risk.

Risk class	*Likely situation*
High	Loose or soft surfaces, a high sand content and exhibiting low moisture retention* Soft or loose unprotected surfaces, and textures heavier than sand exhibiting low moisture retention Highly saline soils with soft or puffy surfaces
Moderate	Firm surfaces, and/or a high sand content, exhibiting moderate moisture retention Firm surfaces, and sand to loam textures
Low	Firm, hardsetting or crusted surfaces exhibiting moderate to high moisture retention Textures heavier than clay loam Stony mantles and/or common to abundant (10->50%) rock outcrop or containing ironstone gravels
Nil	Heavy surface crusts and exhibiting high moisture retention Soils with seasonal, semi-permanent or permanent waterlogging for >3 month a year

* Low moisture retention suggests the topsoil will remain moist for less than one week after rain. Moderate moisture retention suggests the topsoil will remain moist for one week to three weeks after rain. High moisture retention suggests the topsoil will remain moist for more than three weeks after rain.

Flooding risk

Flooding is the temporary covering of land by water from overflowing creeks or rivers and run-off from adjacent slopes or plains. The risk of erosion is directly proportional to the intensity and velocity of overland flow. The following classes describe flooding risk.

Risk class	***Likely situation***
High	Land surfaces covered in water due to sheet flow or catchment overflow at a frequency of at least once per year
Moderate	Land surfaces covered in water due to sheet flow or catchment drainage overflow at a frequency of one in two years, to one in five years
Low	Land surfaces covered in water due to sheet flow at a frequency of one in five years to one in twenty (or more) years
Nil	No flooding frequency

Overland sheet wash flow on a very gently inclined drainage plain

Inundation risk

Inundation is when the land surface is covered by water and the soil is saturated with water. It may be caused by excessive rainfall or seepage. It usually involves very little movement of water over the land surface. This in turn relates to the drainage qualities of the land surface and the soil type. The following classes describe inundation risk:

Risk class	***Likely situation***
High	Water is removed very slowly in relation to supply; soils are inundated for longer than several weeks with seasonal, semi-permanent or permanent water logging for over three months a year
Moderate	Water is removed only slowly in relation to supply. Soils are inundated for up to 12 hours or may be waterlogged for more than one day to several weeks
Low	Water is removed readily in relation to supply; soils are inundated for up to 3 hours or waterlogged for up to one day
Nil	Water is removed rapidly in relation to supply; soils are never inundated or waterlogged

Soil erosion in the survey area

Accelerated soil erosion occurs throughout the survey area but is localised and restricted to a fairly small number of susceptible land surfaces and soil types. It was recorded at 5.3% of the traverse assessments in the survey area (see resource condition chapter). Of the assessments, 4.9% indicated slight, minor or moderate erosion (up to 50% of the surface affected) and 0.4% showed severe or extreme erosion (>50% of the surface affected). Most of the accelerated erosion recorded was caused by water, rather than wind. Sheeting, scalding and rilling were the most common types of erosion observed.

About 144.6 km^2 (or 0.15%) of the survey area was mapped as being severely degraded and eroded (sde). The definition of sde is where there is little or no perennial vegetation remaining and erosion occurs. The soils most frequently affected were duplex types (7a, 7b, 7c, 8).

Many surfaces are protected from erosion by inherent soil characteristics such as stone mantles, well developed cryptogam crusts, hardsetting surfaces or high infiltration rates. Cryptogams are microbiotic assemblages of mosses, fungi, lichens, liverworts or blue-green algae that form thin surface crusts which dominate many hardsetting and crusted soil surfaces. They stabilise the soil and provide protection from rainfall impact and overland flow. The crusting is generally black during the drier months, rapidly greening up after rain. Cryptogam crusts are easily broken by the trampling of livestock, but will re-establish easily if left undisturbed, providing the topsoil has not been severely altered. A loss of cryptogam crusting may lead to erosion of fine soil particles in the first instance and possible larger scale erosion in time (Eldridge and Green 1994).

This excellent cryptogam crusting, mainly of lichens and blue-green algae, indicates a healthy surface and protects the soil from rainfall impact and overland water flow

Soils are protected by landscape attributes such as very gentle slopes on broad plains resulting generally in low energy sheet wash water flows. Many soils are protected by dense vegetative cover particular on loamy plains and sandplains. Disturbance to any of these factors is likely to result in accelerated erosion. In particular, the loss of vegetative cover renders soil surfaces more prone to the effects of wind and water. Those soils which support

vegetation types which are highly preferred by grazing animals (domestic, feral or native) are at risk of erosion unless control of grazing is adequate to prevent loss of vegetative cover.

Table 3 provides wind and water erosion risk ratings of soils associated with various land types and units. In general, soils which are common on **hills, ridges and plateaux** i.e. stony soil (1), shallow red earth (5b) and shallow coarse red sand (2a) are not susceptible to erosion as they are invariably protected by abundant stony mantles. An exception is shallow duplex soil on granite (7a) which is common on breakaway footslopes. These soils have very little surface mantle and frequently have low levels of vegetative cover as they support vegetation which has been preferentially overgrazed. These factors and their texture contrast confer a high risk to water erosion. Traverse records indicate 18.6% of all footslopes showed some form of accelerated erosion (slight to severe).

Most of the common soils in the **stony and loamy plains** have low or low to moderate erosion risk and show little erosion (occasionally slight erosion i.e. <10% of the site affected, or minor erosion 10-25% affected). Some soils such as shallow red coarse clayey sands (2a), are protected by stony mantles. Other soils, particularly those on loamy plains i.e. shallow red earths (5a) and shallow hardpan loams (5d), support fairly dense vegetation with projected foliage cover between 15 and 30%. One common soil on calcrete plains, shallow calcareous loam (5a), was observed to be susceptible to water erosion. Two minor associated soils, shallow red clayey sands on calcrete (2c) and shallow duplexes on hardpan (7c) have moderate to high susceptibility to water erosion.

Sandy soils (2b, 2d, 3a) associated with **sandplains and sandy banks** are protected by vegetation and have high infiltration rates and are generally not susceptible to erosion. However, after fire they are moderately susceptible to wind erosion but stabilise rapidly as vegetation recovers.

The **alluvial plains, drainage zones and lakes** contain a number of common soils such as shallow duplexes (7a, 7c), deep duplexes (8), shallow and deep clays (9a, 9b) and deep red earths (6b) which are inherently erodible. They are subject to higher energy hydrological processes (sheet and channelised flow) than other parts of the landscape, may have sparse vegetative cover and are often eroded.

Erosion was recorded at 124 inventory sites (14.7% of the total). As a group the duplex soils are the most susceptible to erosion, particularly water erosion on unprotected footslopes and drainage floors. The breakdown of erosion for soil types as observed at inventory sites is shown in Table 4.

Table 4. Soil types and erosion at inventory sites

Soil type	No. of sites	Erosion					
		Nil	Slight	Minor	Moderate	Severe	Extreme
Stony soil (1)	45	42	3	-	-	-	-
Shallow coarse red clayey sand (2a)	36	32	2	2	-	-	-
Shallow red clayey sand on calcrete (2c)	11	9	2	-	-	-	-
Shallow red clayey sand (2d)	81	72	5	1	3	-	-
Deep red clayey sand (3a)	90	86	3	-	-	1	-
Deep red sand (3c)	4	3	-	-	1	-	-
Sandy surfaced red earth (4)	14	13	-	-	1	-	-
Shallow calcareous loam (5a)	19	18	-	1	-	-	-
Shallow red earth (5c)	70	63	2	2	2	-	1
Shallow hardpan loam (5d)	75	65	5	2	3	-	-
Deep red earth (6a)	83	75	6	2	-	-	-
Shallow duplex on granite (7a)	31	17	5	7	1	1	-
Shallow duplex on greenstone (7b)	12	6	3	2	1	-	-
Shallow duplex on hardpan (7c)	47	29	5	9	4	-	-
Deep duplex (8)	37	22	7	5	3	-	-
Shallow clay (9a)	32	25	2	3	-	1	1
Deep clay (9b)	34	28	3	1	1	1	-
Cracking clay (10)	9	8	1	-	-	-	-
Juvenile (12)	22	15	2	4	-	1	-
Other soils	54	54	-	-	-	-	-
Sites with no soil description	40	40	-	-	-	-	-
Totals	846	722	56	41	20	5	2

Erosion definitions:

Slight	<10% of soil surface affected
Minor	10-25% of soil surface affected
Moderate	25-50% of soil surface affected
Severe	50-75% of soil surface affected
Extreme	>75% of soil surface affected

Soils and land use

Most of the area is used for pastoralism where native vegetation is grazed by sheep and cattle. Soil management should be a major consideration for successful pastoralism. Maintenance of healthy soils through appropriate stock and vermin control and appropriate positioning of station infrastructure are prime objectives of land managers. Inappropriately positioned tracks, fences or pipelines located on sensitive soils may cause erosion. On stony soils, removal of the stony mantle may lead to track erosion. Tracks across plains carrying sheet flow may channel water and lead to off-site effects such as water starvation of vegetation downslope of major tracks. Breakaway footslopes with duplex soils are highly erodable and should not be disturbed.

While pastoralism is the main land use, mining is the largest economic industry. A small proportion of the area is currently impacted by mining and is mainly confined to the greenstone-based land systems. Mining causes intense but generally localised environmental impacts. The Chamber of Mines of Western Australia, the Australian Mining Industry Council and others have produced guidelines for the mining and exploration industries. As mining is generally not a long-term land use, land rehabilitation and environmental considerations are highly emphasised. Mining organisations are also bound by statutory requirements such as the Mining Act and the Environmental Protection Act.

Tourism is becoming increasingly popular. Several pastoral properties cater for visitors through station stay accommodation and station lifestyle programs. Major towns are also catering for increased numbers of tourists, many of whom are coming to the region to experience outdoor lifestyles or to prospect for alluvial gold. Tourism rarely severely impacts on the land as many tourist facilities are located within townsites or station homestead complexes. There is occasional damage to unsealed roads or tracks especially after rainfall.

Diversification from traditional land uses is becoming more common. Where soils and water supplies are suitable, horticulture has some potential. One pastoral property has a large successful planting of stone fruit while another has begun an emu farm. Further diversification into alternative or multiple land uses is highly likely in the future.

Conservation is another land use. Some broad objectives of conservation bodies is to set aside many different land types and associated soils for conservation purposes. Two former pastoral stations were acquired by the Department of Conservation of Land Management and are now conservation areas. In the future, different land/habitat types may be set aside for conservation, and represented and incorporated, either in a reserve network, or as special areas under co-operative management agreements between existing landholders and CALM.

Rangeland regeneration

Management of areas in poor condition or that are severely degraded and eroded need to be part of a process that includes whole station or mining project management (or any other land use program). Areas that still have reasonably intact soils and seed sources can be recovered in time by manipulating grazing intensity (generally downwards) and season of use. Control of all grazing animals including feral and native species is required.

Areas that are severely degraded and eroded will be more difficult to recover and take a much longer time. The soils most vulnerable under grazing have surfaces which, when continuously disturbed, will eventually break down to fine particles that are easily eroded. The top few centimetres of soil in healthy soil profiles are the most fertile areas for seedling establishment and plant growth. Topsoils of duplex soils have coarse textures of sand and, after initial surface crust decline are highly susceptible to erosion. Below the topsoil, the clayey subsoil is less fertile and usually more saline. If exposed through erosion, the subsoil may become scalded and sealed, with reduced water infiltration rates and much poorer suitability for seedling establishment. Similarly, the topsoils of loamy and clayey soils also have lighter textures than the subsoils and similar scalding to that of duplex soils can occur. Fencing and shutting off artificial waters to exclude, as much as possible, all grazing animals is a first requirement towards re-establishing vegetation. Suitable niches and adequate soil moisture for plant establishment and growth are the most important factors for successful regeneration. Recovery may require the use of expensive techniques involving earth works and reseeding/planting of native species.

Ward (1990), Williams and Shepherd (1991), Scholz (1995) and Addison (1997) detail methods of regenerating degraded rangelands. Specific regeneration techniques will depend on the type of soil and land surface.

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Vegetation

H.J.R. Pringle

This chapter describes aspects of the vegetation in the survey area, building on survey work by Beard (1976) discussed in the earlier review section under the heading ‘Regional vegetation’. A summary listing of major plant families and genera provides the taxonomic context for subsequent description of the vegetation first according to plant forms and second according to the plant communities and vegetation formations they comprise. Regional vegetation patterns across the survey area are then considered. Flora conservation is the final topic addressed.

This chapter focuses on describing the plants and the communities they comprise. The ecological assessment chapter looks in more detail at plant community ecology including integrative aspects of factors and patterns and land use impacts.

Taxonomic summary

The plant taxonomy adopted in this survey is based on Green (1985) and its latest cumulative supplement (No. 7, November 1988), but also adopts changes since then on the advice of the Western Australian Herbarium. Scientific names are used, common names are listed in the appendices.

Table 1. Major families and dominant genera of perennial plant species in the survey

Family	Number of species	Dominant genera
Amaranthaceae	11	*Ptilotus*
Asteraceae	12	*Minuria, Olearia*
Caesalpiniaceae	12	*Senna*
Chenopodiaceae	44	*Atriplex, Halosarcia, Maireana, Sclerolaena*
Chloanthaceae	14	*Dicrastylis, Pityrodia, Spartothammella*
Lamiaceae	29	*Hemigenia, Prostanthera*
Malvaceae	14	*Abutilon, Sida*
Mimosaceae	70	*Acacia*
Myoporaceae	54	*Eremophila*
Myrtaceae	108	*Eucalyptus, Melaleuca, Thryptomene*
Papilionaceae	25	*Bossiaea, Daviesa, Indigofera, Mirbelia*
Poaceae	38	*Eragrostis, Eriachne, Stipa, Triodia*
Proteaceae	45	*Grevillea, Hakea*
Rutaceae	12	*Eriostemon, Phebalium*
Solanaceae	11	*Solanum*

Based on field collections, 719 species of vascular plants are identified representing 222 genera in 63 families (see Appendix 1). These consisted of 638 perennial species and 81 shorter-lived species. This imbalance is to some extent a result of this one-off survey's focus on the perennial flora and its importance in broadscale ecological mapping.

A large number of species belong to a small group of families and genera that characterise the flora in the area surveyed (Table 1).

The Myrtaceae contains the largest number of species (108), many of which occur on sandplains (e.g. *Thryptomene* spp.). Like many other families in the survey area, the Myrtaceae are widely spread throughout Australia. However, at species level many have Eremaean (arid zone) distributions. This is consistent with the idea of radiation of phenologically well adapted biotypes into the arid zone from adjacent, more temperate areas (Barlow 1981, Maslin and Hopper 1981), rather than by internal evolutionary radiation. In some cases, the radiation is believed to have come from the south (e.g. *Eremophila*), while *Senna* is believed to have radiated from tropical lowlands (Randell 1970). The Chenopodiaceae, which dominate saline environments in the survey area and in the Eremaean Zone in general, are members of a cosmopolitan group believed to have evolved from littoral ancestors well adapted to saline, arid environments (Burbidge 1960). Like the Chenopodiaceae, the genus *Triodia* (Poaceae) are characteristic of the Eremaean Zone and are endemic to Australia, rather than cosmopolitan.

Plant forms

The major plant forms observed were trees, mallees, tall shrubs (>2 m), mid shrubs (1-2 m) and low shrubs (<1 m), forbs, grasses, mistletoes, creepers, ferns, sedges (and allies) and soil cryptogams. They are very briefly described below.

Trees

Acacias are dominant in the north-eastern half of the survey area, giving way to eucalypts, *Callitris glaucophylla* and Casuarinaceae south and westwards. Acacias are typically phyllodinous and sclerophyllous. Eucalypts generally have glabrous, laminar leaves with oil glands and canopy diameters occupying a major proportion of tree heights; ‘woodland trees’ and ‘mallees’ according to Brooker and Kleinig (1990). *Casuarina pauper* (black oak) has sclerophyllous, vestigial, erect leaves and photosynthetic branchlets often mistaken for ‘leaves’. Other common trees include *Brachychiton gregorii* (kurrajong), *Bursaria occidentalis* (native box) and *Pittosporum phylliraeoides* (native willow).

Mallees

The mallees in the survey area are usually found on sandplain as open multi-stemmed plants with peeling bark, rarely exceeding 6 m in height (e.g. E*ucalyptus ewartiana* and *E. kingsmillii*). Some are shorter, and more compact with smooth pale bark (*E. leptopoda*).

Tall shrubs

Acacias dominate the tall (>2 m) shrubs in many habitats. *Acacia ligulata* is an exceptional species in having long,

narrow but succulent phyllodes contrasting with the leathery phyllodes of most other wattles in the area. *Hakea* and *Grevillea* are other common shrub genera. *Hakea arida*, *H. preissii* and *H. recurva* have pungent, terete phyllodes, while *H. coriacea* and *H. francisiana* have laminar leaves. *Grevillea* species often have reduced leaves (e.g. *G. berryana*, *G. obliquistigma* and *G. pityophylla*).

Eremophila species are also conspicuous among tall shrubs. The genus exhibits a variety of morphological features such as the pendulous semi-succulent leaves of *E. longifolia* and the viscid leaves of *E. fraseri*. *Calycopeplus ephedroides* is unusual in having succulent stems.

Mid shrubs

This group of shrubs between 1 and 2 m in height is often represented by species of *Eremophila* and *Senna* (formerly *Cassia*). *Eremophila* mid shrubs species vary from the pubescence of *E. forrestii* to the viscidity of *E. fraseri*. Some, such as *E. scoparia* and *E. ionantha* have a broombush habit and terete to semi-terete leaves, while others are more open and have reduced leaves (e.g. *E. latrobei* – warty fuchsia bush). *Senna artemisioides* subsp. *filifolia* (desert cassia) has reduced vernicose phyllodes, while the leaflets of *S. artemisioides* subsp. *helmsii* (crinkle-leaf cassia) and *S. artemisioides* subsp. *artemisioides* are densely hirsute.

Some ericoid (mostly Myrtaceae) heath mid shrubs found on sandplain include *Baekea* aff. *uncinella* and *Malleostemon tuberculatus. Thryptomene strongylophylla* was recorded on banded ironstone ridges and *T. decussata* and *T. mucronulata* were frequently observed around granite exposures.

Low shrubs

Four main groups of shrubs less than 1 m tall can be recognised in the survey area. A large group of shrubs characterised by leaves exhibiting varying degrees of sclerophylly, viscidity and pubescence is often found with *A. aneura*. These species are commonly from the *Senna, Eremophila, Ptilotus* and *Sida* genera. Succulent species are generally represented by the *Maireana* and *Halosarcia* genera of the Chenopodiaceae, with semi-succulent *Atriplex*. Other common succulent species include *Gunniopsis quadrifida* and *Minuria cunninghamii*. These shrubs are generally found together on base-rich, alluvial soils but some, e.g. *Maireana convexa*, occur with sclerophyllous species on more acidic, non-saline soils.

Ericoid low shrubs are common on sandplain and residual surfaces in upland areas such as breakaway plateaux. Some of the species in this group of plants include *Baeckea cryptandroides, B. aff. uncinella, Calytrix desolata, Micromyrtus sulphurea* and *Verticordia interioris*.

The tomentose perennial sub-shrubs (<50 cm tall) that emerge following fire in sandplain are distinctive. They are characterised by the Chloanthaceae: *Dicrastylis, Newcastelia* and *Pityrodia* spp. *Dicrastylis brunnea* var. *brunnea* and *D. exsuccosa* are particularly common, as is *Bonamia rosea* (Convolvulaceae). Presumably the dense layer of leaf hairs reduces warming of the leaf surface by insulation and provides an insulated micro-environment which may help reduce evapotranspiration.

Forbs

The survey was conducted over a period of exceptionally good seasons which supported prolific ephemeral growth. The more common forbs were collected during reconnaissance fieldwork. During the main fieldwork phase new common forbs were also collected. Mulga plains frequently supported greater than a 50% ground cover of forbs, often dominated by *Erodium cygnorum*. This usually small forb attained a height of nearly 1 m in more concentrated flow zones. On sandier soils *Ptilotus polystachyus* often formed a dense herbaceous layer to 1 m tall. Other common *Ptilotus* forbs included *P. aervoides, P. exaltatus, P. helipteroides* and *P. macrocephalus*. *Velleia glabrata* was often dominant on burnt spinifex plains.

A feature of the good seasons, particularly in winter, was the kaleidoscope of colours in the ground storey. Instead of variations of grey-green associated with different acacias, the landscape resembled a patchwork of colours including blue (e.g. *Brunonia australis*), yellow (e.g. *Cephalipterum drummondii, Podolepis canescens* and *Waitzia acuminata*), white (e.g. *Cephalipterum drummondii* and *Rhodanthe chlorocephala* subsp. *splendidum*) and pale mauve (e.g. *Brachycome ciliocarpa, Schoenia cassiniana* and *Velleia rosea*). Red is generally only conspicuous around old (and current) mining centres. *Rumex vesicarius*, an introduced forb, provides this colour.

The good seasons also revealed how common some introduced species have become. Fertile alluvial clay plains below gabbro hills supported a rich introduced ephemeral flora most strikingly represented by thickets of *Carthamus lanatus* to 3 m tall, Cunningham *et al.* (1981) describe this species as occasionally growing to 1.6 m tall. These forb thickets were almost impenetrable on foot. Other common introduced forbs included *Centaurea melitensis, Emex australis* and *Mesembryanthemum nodiflorum*.

A proliferation of paper daisies (Rhodanthe chlorocephala subsp. splendidum) *after an exceptional winter season*

Grasses

Triodia spp. are perennial hummock grasses, a uniquely Australian form of grass in which rigid, pungent involute leaves form a dense hummock. Hummocks senesce outwards to form a ring or contour-aligned band. Hummock grasses occur almost exclusively on sandplain in the survey area, in contrast to areas

further north such as the Pilbara, where a variety of spinifexes also dominates upland stony habitats. Hummock grasses are the most extensively dominant grass form; tussock grasses are usually subordinate to shrubs and trees.

Tussock grasses vary from dense, well developed plants to nearly 50 cm in height such as *Eriachne helmsii* to open, almost herbaceous forms such as *Monachather paradoxa*. The development of a substantial tussock is most common in the *Eriachne* and *Eragrostis* genera (e.g. *Eragrostis eriopoda*). *Amphipogon caricinus* forms particularly dense, erect low tussocks in sandy soils. *Eragrostis australasica* forms dense stands to over a metre in height in swamps, but was rarely encountered. *Stipa elegantissima* is a very palatable species which occurs almost exclusively as an open grass growing within and supported by low and mid shrubs such as *Cratystylis subspinescens*.

As with the forbs discussed above, herbaceous grasses were abundant during the survey reflecting the exceptionally good seasons in 1992 and 1993. This was particularly so on calcrete platforms, where *Stipa nitida* formed tight erect plants at a density similar to a wheat crop. *Aristida contorta* is an open, narrow-stemmed grass with conspicuous three-awned seeds, and *Eragrostis dielsii* is a small, often decumbent grass commonly found with chenopod shrubs. *Pentaschistis airoides* is a low (<15 cm) introduced annual grass with fine stems and foliage that was commonly encountered. Other introduced annual grasses include *Phalaris minor* and *Polypogon monspeliensis*.

Mistletoes

Mistletoes are epiphytic parasites commonly found growing on the branches of acacia, eucalypt and casuarina species. Their foliage is very variable and often resembles that of their host. Their seeds are eaten by birds and disseminated in droppings (Reid 1986, Yan 1993), thus they are very common in overstoreys adjacent to water points which birds frequently visit to drink. *Amyema* and *Lysiana* are the two mistletoe genera.

Creepers

Creepers were common in the survey area, often growing on *Acacia aneura* tall shrubs and trees. *Marsdenia australis* has woody stems and produces a large, pear-like fruit to 8 cm long whose seeds are nutritious. *Comesperma integerrimum* is less lignified and bears a flattened, fleshy fruit. *Thysanotus manglesianus* forms tight vines on host branches and has conspicuous, ornate purple flowers, while *Rhyncharrhena linearis* has long, pendulous pods. None of these species is parasitic.

Sedges and allies

Sedges were encountered in ephemeral wetlands such as around pools in creeks. *Cyperus* species were common. Sandplains in the south-west often supported dense stands of *Ecdeiocolea monostachya* (Restionaceae).

Ferns

Three species were recorded. *Cheilanthes austrotenuifolia* is a nearly glabrous, delicate plant found in a variety of habitats; *C. lasiophylla* is a prostrate tomentose plant usually found in rock crevices; while *C. sieberi* subsp. *sieberi* has densely clustered fronds and is found in a number of habitats including mulga woodland.

Soil cryptogams

Soil cryptogams consist of unicellular algae, liverworts, and foliose and crustose lichens. They are a largely neglected part of the flora whose role in soil ecology in arid zones has only recently been widely recognised in Australia (e.g. Tongway and Greene 1989). They stabilise naturally dispersive soils and reduce the impact of rain drops which cause erosion by dislodging soil particles. They also provide forage for microscopic herbivores, hence contributing both directly and indirectly to biological activity at the soil surface. Cryptogams were not collected in this survey, but were collected in the north-eastern Goldfields (Pringle *et al.* 1994) and in an ecological survey of Wanjarri Nature Reserve in 1994 (Cranfield and Fang in prep.). Foliose lichens and mosses are often restricted to granite outcrops and drainage tracts with close upperstoreys of tall shrubs and trees providing shade in relatively insulated environments.

Vegetation formations and their floristic components

Vegetation formations described below have been developed from inventory site data using a ranked stratum approach. The strata include the following:

Trees:	plants with a single stem at a height of 1.3 m above ground level
Mallees:	multi-stemmed eucalypts
Tall shrubs:	shrubs over 2 m tall
Mid shrubs:	shrubs 1 to 2 m tall.
Low shrubs:	shrubs less than 1 m tall
Grasses:	tussock and hummock grasses (perennial grasses)

This is a simplification of traditional methods of describing vegetation (e.g. Specht 1970; Beard and Webb 1974; Muir 1977 and Wilcox and Fox 1995). Muir's formations are referred to within each broad formation described below. Some aggregation has taken place. For instance, a small number of tree and tall shrub dominated sites classified according to Muir as Low Forest and Thicket have been described under Woodlands and Tall shrublands respectively.

Tall shrubs provided the most common dominant stratum at inventory sites, followed by low shrubs, trees, mid shrubs and perennial grasses respectively (Table 2). While tall shrublands were most common on all map sheets, there is noticeable geographic variation in other strata.

Trees are considerably more common on the Barlee and Perenjori sheets than elsewhere, mid shrublands are most common on the Yalgoo and Perenjori (western) map sheets, low shrublands are most common on the Kirkalocka, Sandstone and Youanmi (north-eastern) map sheets and perennial grasslands are common on the Youanmi and Sandstone (north-eastern) map sheets.

Table 2. The proportion of (%) dominant or co-dominant strata[1] recorded at inventory sites on the 1:250,000 map sheets

Map sheet	Tree	Tall shrub	Mid shrub	Low shrub	Perennial grass
Barlee	29	42	3	24	2
Kirkalocka	8	46	7	38	1
Ninghan	14	54	8	23	1
Perenjori	23	55	14	7	2
Sandstone	14	40	8	31	6
Yalgoo	9	56	13	22	0
Youanmi	9	48	4	34	5
Average	15	49	8	26	3

[1]Mallees lower than 4 m were treated as shrubs, and those taller as trees.

These patterns are consistent with the regional overview of Beard (1976), reflecting a change from mulga and spinifex dominance of the Eremaean Botanical Province in the north east of the survey, towards the acacia/casuarina/*Eucalyptus loxophleba* dominated South-Western Interzone and South-West Botanical Province to the south and west respectively.

Woodlands

Most tree dominated sites have a canopy height from 4 to 10 m and canopy cover ranging from 10 to 30%. They are thus mostly 'Low Woodland A' according to Muir (1977). A few 'Low Forests A' (canopy cover > 30%) of *Acacia aneura* or a range of eucalypts were recorded.

While 35 dominant tree species were recorded, approximately half of these sites were dominated by *Acacia aneura* or *Eucalyptus loxophleba*. Twenty one eucalypts and five acacias were dominants at woodland sites.

Acacia aneura woodlands occur on the deeper red earths in the north-east of the survey area, with *Eucalyptus gongylocarpa* on sandplains and dune fields. Further south, *Callitris glaucophylla* is common on the coarser and deeper red earths and sandplains. *Allocasuarina acutivalvis, A. campestris* and *Casuarina pauper* (black oak) woodlands are common in the south, along with communities dominated by *Eucalyptus salmonophloia, E. salubris* and *E. loxophleba*. The Casuarinaceae are more conspicuous than eucalypts in upland greenstone and ironstone woodlands in the south-east; the eucalypts dominating woodlands on alluvial tracts in this part of the survey area. *E. salmonophloia* and *E. salubris* are generally found on heavier textured soils than the red earths where *E. loxophleba* is predominant. This is also reflected in the understorey, with chenopods dominating on the heavier soils and sclerophyllous species on the red earths.

Mallees

Mallees rarely dominate plant communities in the survey area, usually occurring in acacia dominated communities in the south and west or Triodia basedowii hummock grasslands in the north-east. Occasionally, *Eucalyptus ewartiana, E. kingsmillii* or *E. leptopoda* may dominate sandplain communities of 'Open Shrub Mallee' (Muir 1977).

Tall shrublands

Tall shrublands characteristically range from 10 to 30% projected foliar cover, usually attaining a height of between 2 and 5 m. According to Muir (1977), these sites are 'Scrub'. Occasional 'Thicket' with foliar cover exceeding 30% was recorded, usually dominated by acacias. Thickets occurred in areas receiving more concentrated run-on and were often dominated by *Acacia acuminata* or *A. aneura*. Some *A. coolgardiens*is thickets on sandplain were also sampled. 'Open Scrub' (canopy cover <10%) was occasionally recorded at upland sites with very shallow, stony soils.

Acacias dominate the overwhelming majority of tall shrublands in the survey area. Species such as *A. quadrimarginea* dominate a particular habitat (around rock outcrops in this instance) throughout the survey area, while others have a particular geographic affinity. *A. aneura* is the most common dominant species in the north-east of the survey area (a geographic affinity shared by *A. craspedocarpa*), while *A. acuminata* is commonly dominant in the south.

Hardpan plains characteristically dominated by *A. aneura* throughout the Eremaean Botanical Province (Wilcox and McKinnon 1972, Payne *et al.* 1982, Pringle *et al.* 1994) are as frequently dominated by other acacias such as *A. acuminata, A. grasbyi* or *A. ramulosa* in the south and west of the survey area.

Among the other common conspicuous tall shrub species are *Acacia coolgardiens*is on sandplains, *A. masliniana* on alluvial plains with chenopods, *A. tetragonophylla* on hardpan plains and drainage tracts, and *Melaleuca uncinata* around granite outcrops and on sandplains.

Hail damage to large areas of *Acacia aneura* and *A. ramulosa* communities was observed. While the understorey appeared to have increased in cover and density, regeneration of acacias was patchy. The opening up of these communities has had a similar effect to fire (Curry 1986), increasing pastoral value in some cases. It remains to be seen whether the overstorey species will regenerate successfully.

Mid shrublands

Most mid shrublands sampled had a projected foliar cover between 10 and 30%, making them 'Low Scrub A or B'

according to the Muir classification system. 'Heath' (cover > 30%) was recorded on sandplains dominated by acacias or myrtaceous shrubs referred to below.

Mid shrublands are uncommon and have highly variable dominant species including immature acacias such as A. *ramulosa* and *A. coolgardiensis* (particularly in post fire successions), heath species on sandplains such as *Baeckea* aff. *uncinella, Thryptomene deccussata* and *T. mucronulata* around granite exposures and *Senna* and *Eremophila* spp. on stony plains (e.g. *Senna artemisioides* subsp. *sturtii* and *E. fraseri*). *Eremophila forrestii* is occasionally dominant around granite outcrops and on areas with deep coarse red earths where the overstorey acacias have died due to disturbances such as hail or have senesced and not been replaced. In some halophytic communities, species such as *Maireana pyramidata* and *Lycium australe* may develop into a dominant stratum over 1m in height. A disjunct *Atriplex nummularia* ssp. *spathulata* population was sampled on Windimurra station near Mount Magnet. It is common around Kalgoorlie and on the Nullarbor Plain and is not known to occur elsewhere in the survey area north of Lake Barlee. Another disjunct distribution occurs near Shark Bay (Wilson 1984). The *A. nummularia* communities occurred on fertile alkaline alluvium derived from gabbro similar in nature to some soils around Kalgoorlie.

Low shrublands

Most low shrub dominated communities had a projected foliar cover in the range of 10 to 30%, making them 'Dwarf Scrub A or B' according to the Muir (1977) vegetation classification system. 'Low Heath' (cover >30%) was occasionally sampled at sites on sandplain and particularly harsh upland habitats and degraded chenopod shrublands were 'Open Dwarf Scrub C or D' (cover <10%).

Low shrublands were generally the second most common vegetation formation, being least common in the south-west of the survey where overstorey tall shrubs and trees dominate the vegetation.

Table 3. The floristic variability and frequency of dominant strata

Dominant stratum	No of species[1]	No of sites
Tree	35	122
Tall shrub	46	432
Mid shrub	38	69
Low shrub	57	245
Perennial grass	7	21

[1] This includes sub-species and aff. species as individual species

Tall shrublands were the most commonly sampled vegetation formation. However, with only half as many sites, there were more species recorded as dominant or co-dominant in the low shrub stratum (Table 3). This highlights the considerable ecological indicator (e.g. habitat indicators) information contributed by this stratum. This information is particularly important in identifying different habitats with common overstorey species. For instance, *Acacia aneura* was recorded as the dominant or co-dominant species at 116 tall shrubland or woodland inventory sites, encompassing 22 different habitats (see the Ecological Assessment chapter of this report). Thirty five different species were recorded as the dominant low shrub at *Acacia aneura* dominated shrublands or low woodlands.

Low shrublands occur most frequently as chenopod succulent steppe and less frequently as non-succulent communities. The succulent shrublands are generally dominated by the Chenopodiaceae genera *Atriplex, Halosarcia* and *Maireana*, although these communities may also be dominated by *Cratystylis subspinescens*, *Frankenia* spp. and *Gunniopsis quadrifida*. The most frequently dominant chenopods are *Atriplex bunburyana, A. vesicaria, Halosarcia* spp., *Maireana pyramidata* and *M. triptera*. In some instances, particularly in historically overgrazed communities, non-succulent low shrubs such as *Eremophila malacoides* and *Ptilotus obovatus* may have succeeded chenopods as dominants.

Two main groups of non-succulent low shrublands were encountered, those associated with *Acacia aneura* on red earths and a suite of species typified by the Myrtaceae and found on sandplain and residual upland surfaces. The former group is frequently dominated by the *Eremophila* genus, including *E. forrestii* and *E. fraseri*, and by *Ptilotus obovatus*. Unlike chenopod low shrubs, where these species dominate they often occur with easily recognisable, but subordinate overstorey strata typified by *Acacia aneura, A. acuminata* ssp. *burkittii, A. quadrimarginea* or *A. ramulosa*.

The second non-succulent group occurs as low heath on sandplains and as dwarf scrub on duricrusts, stripped surfaces and ridges in upland areas with poorly developed mid and tall shrub strata. Both the sandplain and upland communities are characteristically highly variable in terms of dominant species, including representatives from *Baeckea, Calytrix, Eriostemon, Thryptomene* and *Verticordia*.

Another group of species in the north-east of the survey area, associated with post fire successions in hummock grasslands, commonly forms (seral) low shrublands. Some of the more common species dominant in these communities include *Dicrastylis exsuccosa* and *Leptosema chambersii*. They may persist for up to five years before spinifex resumes its dominance.

Perennial grasslands

Most perennial grasslands occur in deep, well-drained, coarse-textured soils. Four groups of perennial grasslands can be distinguished, only one occurring in drainage features. These are described below in order of increasing drainage influence and clay content of their soils.

'Mid Dense Hummock Grass' (Muir 1977) communities are extensive in the north-east of the survey area. They occur on sandplains with deep red aeolian sands typical of landscapes of the interior of Western Australia. *Triodia basedowii* is the most common spinifex, often forming almost monospecific stands. *Triodia rigidissima* is common south of Sandstone, but is often subordinate to tall shrubs and mallees. Hummock grasslands are susceptible to wildfires from lightning strikes during dry summer thunderstorms. A range of herbaceous plants usually emerges with rains in recently burnt areas and are usually succeeded by spinifex.

Pastoralists use prescribed burning to improve the pastoral value of hummock grasslands as the herbaceous communities include many palatable forbs and grasses (Wilcox 1972; Tauss 1991, Williams and Tauss 1991). Wilcox (1972) proposes a fire frequency of approximately every 15 years, four or five of which are years of improved pasture followed by about 10 years during which spinifexes mature to a size and density able to support a fire again. This prescription is aimed at improving pastures; its impact on other values, such as nature conservation, is not well understood.

Amphipogon caricinus and *A. strictus* may emerge to dominate areas of burnt spinifex sandplain for a few years. These species are sometimes dominant on sandplains with buff sand and gravel. *Amphipogon* 'Open Low Grass' communities do not support the same fuel loads and are hence only likely to support fires following particularly good summer rains.

Wanderrie grasses occur on sandy banks on mulga hardpan plans and in areas receiving diffuse run-on with deep (>60 cm) sandy loam and loamy sand soils. They are low tussock grasses which form 'Open Low Grass' or 'Low Grass' communities with foliar cover ranging from 10 to over 50% in good seasons. *Monachather paradoxa* is most commonly dominant in these communities, often accompanied by *Eragrostis eriopoda* and *Thyridolepis multiculmis*. *Eriachne helmsii* is less frequently observed in these communities and is sometimes associated with overgrazing (Mitchell and Wilcox 1994; Pringle 1994). *Eragrostis eriopoda* is more extensively dominant in the more arid north-eastern Goldfields (Pringle *et al.* 1994).

Although tussock grasslands are only a minor formation in the area, Monachather paradoxa *(broad-leaved wanderrie) is a perennial grass common in many shrubland communities*

Tussock grasses also occur less extensively in drainage features. Alluvial plains below hills of gabbro often have gilgai microtopography in central drainage tracts and groves with cracking clay soils. *Eragrostis setifolia* often dominates these areas as 'Open Low Grass' communities (Muir 1977). *Eriachne flaccida* frequently dominates small (less then 100 m wide) drainage foci in the lower sectors of mulga plains, also as 'Open Low Grass' communities. *Eragrostis australasicus* is a rare plant in this region, dominating 'Tall Grass' canegrass swamp communities, attaining over 50% projected foliar cover. These drainage feature grasslands represent fertile patches in characteristically infertile landscapes and may prove to have considerable regional importance with regard to the habitats they provide for native fauna.

Regional distribution of plant communities

This survey area encompasses a considerable variety of plant communities reflecting the inclusion of taxa from the Eremaean Botanical Province, the South-Western Interzone and the South-west Botanical Province (Beard 1990). The structural complexity and cover of the vegetation generally increase southwards and westwards through the survey area, and are accompanied by changes in floristic composition.

This geographical variation is easily recognisable when regional vegetation differences on similar land surfaces/soil types are considered. Sandplains, sheetflood plains with red earths on hardpan, duplex alluvial plains downslope of granite breakaways and banded ironstone ridges all exhibit this regional variation in vegetation characteristics.

North of Sandstone, in the north-east of the survey area, sandplains support *Triodia basedowii* hummock grasslands with scattered acacias, mallees, *Grevillea* and heath species. Fire scars on recent 1:50,000 scale black and white aerial photographs are numerous and their different tones indicate seral stages. South of Paynes Find, the shrubs and mallees are frequently dominant on sandplains with a sparser *T. basedowii* groundstorey, and heath becomes more conspicuous south of Lake Barlee. *Triodia rigidissima* and *T. scariosa* are also common south of Sandstone, the latter more so south of Lake Barlee.

Sandplains west of the three eastern 1:250,000 map sheets (Sandstone, Youanmi and Barlee) support little or no hummock grass. Instead, close tall shrublands dominated by distinctive species such as *Acacia sibina*, *A. longispinea* and *Melaleuca uncinata* predominate, with lower shrubs (<2 m tall) including *Baeckea elderiana*, *Melaleuca cordata* and *Thryptomene aspera* ssp. *glabra*. Also distinctive of the western sandplains is *Ecdeiocolea monostachya*, a member of the Restionaceae, which dominates these communities in some areas.

Sheetflood plains with red earths (usually sandy clay loams) on hardpan (hardpan plains) characteristically support scattered *Acacia aneura* tall shrublands/woodlands in the Eremaean Botanical Province, as is the case on the north-east of this survey area. However, in the south-west of the area, other acacias are frequently dominant on these plains including *A. acuminata* ssp. *burkittii*, *A. grasbyi* and *A. ramulosa*. Some of the subordinate species are also not commonly seen in hardpan plain communities dominated by *A. aneura*, including *Grevillea obliquistigma*, *G. pityophylla*, *Hakea recurva* and *Stipa elegantissima*.

Breakaways form imposing scarps on weathered granite. In the Ashburton, Gascoyne and Murchison River catchments their footslopes usually support succulent low shrublands dominated by *Atriplex*, *Frankenia* and *Maireana* species. In the south of this survey however, as on Mouroubra station near Lake Moore, these footslopes and adjacent alluvial plains have a well developed eucalypt overstorey. On Mouroubra station, *Eucalyptus loxophleba* woodlands are common in these areas over a mixed *Atriplex/Maireana* understorey.

Banded ironstone ridges such as the Booylgoo Range in the far east area support a typical Eremaean sclerophyll shrubland, with *Acacia aneura*, *Eremophila fraseri* and *Ptilotus obovatus* prominent. Projected foliar cover is generally less than 20%. South of Lake Barlee and continuing westwards along the south of the survey area and

then north along the western boundary towards Tallering Peak, the vegetation on banded ironstone ridges is considerably denser, more complex and floristically variable. On Mount Elvire station south of Lake Barlee in the far south-west of the survey area there are pockets of *Dryandra arborea* woodland. On Tallering Peak, in the far north-west, a community dominated by *Eriostemon sericeus* and *Thryptomene decussata* was sampled. Other species found in the north-west but not on north-eastern (Eremaean) ridges included *Baeckea pentagonantha, Dodonaea inaequifolia, Lobelia heterophylla, Micromyrtus racemosa* var. *prochytes* and *Thryptomene strongylophylla*. These ridge crest communities were low to mid shrublands (<2 m tall), while the ridge slopes had many of the same understorey species as the crests, but supported acacia tall shrublands with over 30% foliar cover.

Some plant communities occur in soil types with restricted distributions in this survey area. For instance, chenopod/tussock grass mosaics are confined to alluvium derived from gabbro hills such as those on Windimurra station between Sandstone and Mt Magnet. The gabbros extend north into the Murchison River catchment survey area (Curry *et al.* 1994) and south into Youanmi station. *Atriplex nummularia* communities on Windimurra station are also confined to plains downslope of gabbro uplands.

Casuarina pauper (Low Woodland A) communities are mostly confined to plains with calcrete inclusions in their soil profiles. These occur in the south-west corner adjacent to Lake Barlee, but are more common to the east of this survey area (Pringle *et al.* 1994). *Eucalyptus salmonophloia* and *E. salubris* woodlands with chenopod understoreys occur on alluvial plains with clay soils in the south of the survey area. Further north these plains usually have texture contrast soil profiles and may support scattered acacias within chenopod communities.

Regional patterns of vegetation distribution therefore reflect both climate and physical environmental factors.

Flora conservation

Flora conservation involves maintaining biological diversity at a variety of scales, from the genetic diversity within single populations to continental and global species richness. In this section, the conservation of plant species and communities in terms of threats to them, and a Declared Rare and Priority Flora List for the survey area (updated from Hopper *et al.* 1990) are discussed.

Threats to native flora

Pastoralism

Pastoralism has extensively modified native rangeland plant communities. Where grazing has been excessive, species palatable to domestic stock (sheep and cattle), feral animals (goats and rabbits) and kangaroos have been substantially reduced or removed. Replacement by suites of less palatable species well adapted to establishing in vacated niches rarely equals the species richness, density or cover of previous communities (see the Ecological Assessment chapter).

Two key factors affect the distribution of grazing pressure in pastoral paddocks, distance from water and grazing preference. Cridland and Stafford Smith (1993) have shown that grazing impacts are disproportionately severe in proximity to stock water points. If one considers the area surrounding a water point as a series of concentric bands, each successive band of equal width travelling out from the water point has an area considerably greater than the previous one due to the $\prod r^2$ function for calculating the area of a circle. The r^2 makes the area within 1 km of a watering point a third of the area between 1 and 2 km from the water point. This piosphere effect (Lange 1969) is particularly evident in large paddocks (>50 km^2) where stock are constrained by the need to drink regularly in hot weather and thus cannot readily access all of a paddock (Cridland and Stafford Smith 1993).

In most paddocks, where grazing animals have ready access to all areas, the severity of modification is as much a function of grazing preference as distance from water points (Cridland personal communication). In this respect, chenopod shrublands are most frequently preferentially grazed as they support palatable shrubs. Palatable shrubs may be killed by grazing when herbaceous matter is scarce in poor seasons. Palatable shrubs usually dominate structurally simple chenopod communities and thus their removal causes severe modification in terms of loss of plant cover and increased exposure of soils which are frequently susceptible to soil erosion.

Grazing impacts are also disproportionately greater along fence lines which break stations up into paddocks, as evidenced by increased albedo reflectance in LANDSAT images of parts of the Nullarbor Plain (Hacker personal communication).

The introduction of cloven-hooved domestic herbivores, coupled with the installation of fencing and water points, has thus led to the systematic modification of native ecosystems. The degree or level of grazing modification is variable and uneven depending on the location of developed water points and fences, the spatial arrangements of preferred and less preferred vegetation communities (and their sensitivity to grazing) within a paddock.

Chenopod low shrubland communities have been most severely modified, partly as a result of preferential grazing, and also because most plants in these communities are palatable and accessible to grazers. In *Acacia aneura* communities, structural development is greater and grazers only affect the sparse palatable component of the understorey and hence the modification is usually considerably less severe.

At a species level, there are no plants known to have become extinct in the survey area, or in the arid shrubland rangelands of Western Australia for that matter, since pastoralism was introduced. However, it is likely that the distribution of highly palatable species such as *Maireana platycarpa* has been reduced with consequent reductions in genetic diversity at a species level. Similarly, trees such as *Santalum spicatum* and *Acacia papyrocarpa* are unlikely to be killed by grazing, but appear to have difficulty in recruiting new individuals because their seedlings and juveniles are grazed preferentially.

In terms of flora conservation alone, it is inadvisable for pastoralists to spread introduced species such as *Cenchrus ciliaris*. To date, no introduced 'wonder weed' species have been successfully established on a large enough scale to markedly improve pastoral production or threaten native habitats in the survey area. This may be because introduced species have generally come from climates with very mild

winters and are unable to survive regular very cold periods in winter.

Feral herbivores

Feral goats pose the greatest threat to flora conservation of all feral herbivores in the survey area. Studies at Yerilla station in the north-eastern Goldfields (Fletcher 1991) show that goats are considerably better adapted to the shrubland rangelands than sheep. While sheep suffered during dry periods and at high stocking rates, goats continued to breed successfully. The goats' hardiness and pastoralists' inability to control them with conventional sheep fences make them a significant threat to flora conservation. This important species of vermin is discussed in greater detail in the Declared Plants and Animals chapter.

Rabbits also pose a threat to native flora, but their impact is more localised by the limited distribution of suitable substrates in which to excavate warrens, such as occur adjacent to salt lakes and around groundwater calcretes. Their abundance fluctuates considerably with seasons. Any control of foxes and cats to reduce predation on small native fauna species may need to consider the implications of reduced predation in areas of rabbit infestation in an integrated vermin control strategy.

Kangaroos

Kangaroo numbers are unnaturally high in pastoral country due to the provision of permanent water supplies at watering points (Oliver 1986, Norbury 1992). This results in additional grazing pressure on native plants. As with feral goats, kangaroo grazing is largely uncontrolled because of the ineffectiveness of conventional sheep fences. Kangaroos have been shown to retard regeneration programmes in areas from which stock have been excluded to encourage recovery (Gardiner 1986a,b, Norbury and Norbury 1991). A method of selectively denying kangaroos access to stock water points using electrified wires has recently been investigated (Norbury 1992). It aims to reduce kangaroo numbers to approximately those that would occur under conditions of natural water availability only.

Mining activity

Of more than 10,000 traverse assessments over the survey area, only 31 (<0.3%) recorded obvious mining impacts; fire impacts were recorded at 35 assessments. Mining activity generally has profound but very localised impacts on native habitats (Pringle *et al.* 1990). Thus, a major threat from mining is the clearing of areas in which populations of rare or endangered flora exist. Species such as *Grevillea inconspicua* are found in greenstone belts which attract a disproportionately high level of mining activity. This report and the accompanying maps highlight areas where these populations may occur, but considerably more detailed survey is required to assess possible impacts of proposed mining activity on flora conservation. The biological surveys conducted by environmental consultants on behalf of mining companies aim to identify these populations.

An indirect threat posed by mining is in the introduction of non-local species, including the possibility of accidentally disseminating declared weeds. The use of local species and seeds for rehabilitation programs will prevent any possible succession of local plants by physiologically better adapted biotypes or introduced species. It appeared, from traverse observations, that introduced species do not readily invade undisturbed areas. At the moment at least, the impact of weeds on intact habitats has generally been localised.

Declared Rare Flora (DRF) and Reserve Listed Flora

This section concentrates on flora conservation at a species level. Plant community conservation is addressed in the Ecological Assessment chapter of this report.

The Department of Conservation and Land Management (CALM) maintains a Declared Rare and Priority Flora List (updated from Hopper *et al.* 1990) under provisions of the Wildlife Conservation Act.

Sixty six species in the survey area are on the Declared Rare and Priority Flora List, with six of these being Declared Rare Flora (Table 4). Nearly half of the Priority species are not known to occur on lands set aside for nature conservation. The management of these species on pastoral lands is an important issue and will require the cooperation of pastoralists, their Land Conservation Districts Committees and CALM as has occurred for *Grevillea inconspicua* on Lake Mason station.

Hussey and Wallace (1993) discuss the management of native bushland in agricultural areas of Western Australia in a book titled *Managing Your Bushland*. Many of the underlying principles and concepts in this work also apply to managing rangeland beyond pastoral production and may serve as a useful reference. Very little research has been undertaken regarding pastoral management for the maintenance of biological diversity. Morton *et al.* (in press) and Pringle (1995) propose a regional approach to managing biological diversity and briefly consider possible mechanisms by which pastoralists can become more active stewards of the land for the wider community as well as continuing their primary production. Curry and Hacker (1990) emphasise the importance of conservative pastoral management to preserve the integrity of native habitats, a principle endorsed by CALM (1992). In general, areas in good range condition are more likely to have maintained conservation value than overgrazed areas.

Verticordia interioris, *a priority 3 species, occurs occasionally in granitic habitats*

Table 4. Declared Rare and Priority Flora Listings for the survey area (source Hopper *et al.* 1990 and latest unpublished supplement October 1994)

Taxon	Collection number[1]	Priority code[2]
Darwinia masonii		R
Eucalyptus crucis subsp. *praecipua*		R
Eucalyptus synandra		R
Grevillea inconspicua	6757	R
Stylidium merrallii		R
Tetratheca paynterae MS		R
Acacia cerastes MS		1
Acacia imitans		1
Acacia inceana subsp. *conformis*	3965	1
Acacia unguicula		1
Allocasuarina tessellata	30228	1
Baeckea sp. London Bridge		1
Baeckea sp. Paynes Find		1
Baeckea sp. Perenjori		1
Calothamnus superbus	3137	1
Calytrix creswellii	3401	1
Calytrix uncinata		1
Calytrix verruculosa	3344	1
Chamaelaucium sp. Yalgoo		1
Epacridaceae gen. nov.		1
Grevillea scabrida	3856a	1
Grevillea subtiliflora		1
Hybanthus cymulosus		1
Labichea eremaea		1
Labichea obtrullata		1
Leptospermum macgillivrayi		1
Microcorys tenuifolia	3994	1
Micromyrtus racemosa var. *mucronata*		1
Persoonia karare MS		1
Pityrodia canaliculata	3668	1
Rhodanthe collina		1
Ricinocarpos brevis MS		1
Stenanthum sp. Yeelirrie		1
Acacia subrigida	3847	2
Acacia subsessilis MS		2
Calytrix erosipetala		2
Eucalyptus educta		2
Grevillea stenostachya	3327	2
Hemigenia brachyphylla	3218	2
Leucopogon breviflorus	3358	2
Spartothamnella puberula	3707	2
Stenanthum poicilum		2
Verticordia jamiesonii		2
Acacia acanthoclada subsp. *glaucescens* MS		3
Acacia formidabilis MS		3
Acacia isoneura subsp. *isoneura* MS		3
Acacia kalgoorliensis MS	3034	3
Acacia speckii MS	3339	3
Baeckea microphyllum		3
Baulostion microphyllum	3280	3
Calytrix praecipua		3
Dicrastylis linearifolia	3501	3
Eriostemon nutans	3851	3
Grevillea eriobotrya	3433	3
Grevillea georgeana	30101	3
Grevillea globosa	3333	3
Hemigenia saligna	3382	3
Mirbelia stipitata		3
Verticordia interioris	3067	3
Verticordia venusta		3
Eucalyptus formanii	3431	4
Eucalyptus nigrifunda		4
Goodenia neogoodenia		4
Grevillea erectiloba	3148	4
Prostanthera magnifica	3145	4
Wurmbea murchisoniana		4

[1] Collection number: Rangeland survey specimen collecting number

[2] Priority codes:

R Declared Rare Flora (DRF).
1 Taxa with few poorly known populations on threatened lands
2 Taxa with few poorly known populations on conservation lands
3 Taxa with several poorly known populations, some on conservation lands
4 Rare taxa, not currently threatened, but require monitoring

Conclusion

The survey area is particularly diverse for Western Australia's rangelands, reflecting the convergence of the Eremaean and South-West Botanical Provinces and the South-Western Interzone (Beard 1990). Seven of Beard's Primary Vegetation Types occur in the survey area, one each from the South-Western Interzone and South-West Botanical Province and five from the Eremaean Botanical Province. The flora is essentially Eremaean, with most species occurring extensively further north and east. *Casuarina pauper* woodlands represent the 'Mixed dry woodlands' of the South-Western Interzone and *Eucalyptus loxophleba* is more extensively distributed in the northern wheatbelt to the south-west.

Much of the flora exhibits adaptations to infertile soil and an arid climate. Sclerophyllous phyllodes typify the acacias and varying degrees of pubescence and viscidity are common in eremophilas. Succulence typifies the flora found growing in base rich, often saline soils as occur extensively adjacent to bare salt lake beds. This survey area contains the south-western limit of spinifex hummock grasslands and the impressive marble gum, *Eucalyptus gongylocarpa*, which together characterise much of the sandplain of Western Australia's interior. Spinifexes are a uniquely Australian plant form exquisitely adapted to an extremely harsh climate with nutrient deficient soils.

There is a trend to denser, more structurally complex vegetation travelling from the mulga and spinifex dominated north-east of the survey area towards the wheatbelt south of Lake Moore in the south-west. This is illustrated by the preponderance of overstorey eucalypts in what are open low shrublands further north-east. The spinifex hummock grasslands in the north-east also give way to dense mixed shrublands near the wheatbelt. These regional patterns are heavily influenced by a more reliable and mesic climate travelling south-westwards. Soil types are also influential, as with the occurrence of *Casuarina pauper* woodlands on

plains with calcareous soils adjacent to Lake Barlee in the south-west of the survey area.

It appears that European activities including pastoralism, mining and tourism have modified this area's vegetation, but not as substantially as in rangelands further north (e.g. Wilcox and McKinnon 1972). This is partly due to the extent of vegetation of negligible pastoral value; spinifex hummock grasslands and thickets, heaths and low heaths on similarly deep, sandy infertile soils. Chenopod low and dwarf scrub has been most extensively and substantially altered, both in appearance and with respect to ecosystem function. These formations support vegetation preferred and accessible by stock, feral animals and kangaroos. Even so, much of this formation remains intact and the vegetation of the survey area may generally be considered to be in good condition (see the Resource condition chapter of this report).

The formal integration of nature conservation and primary production objectives has commenced in this area. Land managers have a major contribution to make to regional conservation. As yet there are no formal public incentives such as remuneration or tax deductions available for managers willing to adopt specific nature conservation activities. Pastoralists have a major role to play in feral animal control. Uncontrolled grazing by feral goats has left scars on the region's vegetation and their control (and hopefully eradication) will make substantial progress towards ecological sustainability in the region.

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Ecological assessment

H.J.R. Pringle

Habitats as ecological units

The interrelationships between the physical environment and the plant communities it supports can be described by classifying sampling points (inventory sites) into habitats. Habitats occur as and are described in terms of combinations of landforms, soil types and plant communities. They most closely resemble the 'ecological site' of the Society for Range Management (1991) and the 'habitat' of Tinley (1991). In previous rangeland surveys in Western Australia, habitats have been termed 'pasture lands' (Payne *et al.* 1988), 'pasture types' (Payne *et al.* 1987), 'vegetation types' (Curry *et al.* 1994) and 'site types' (Pringle *et al.* 1994). 'Habitat' was chosen as it most accurately fits the ecological classification below and means something to those not familiar with rangeland survey.

The classification below (Table 1) has been developed from previous surveys immediately to the north (Curry e*t al.* 1994) in the Murchison River catchment; and to the east (Pringle *et al.* 1994) in the north–eastern Goldfields. These previous classifications were developed using numerical taxonomic packages. In this survey habitats were adopted from those sources and were augmented by new ones recognised during the survey. This occurred particularly in the south and west of the survey area, with the influence of the South-Western Interzone and South-West Botanical Province (Beard 1976, 1991).

Habitats are described within broader habitat groups so as to aggregate ecologically similar habitats. Habitat groups have generally similar landscape position as well as similar vegetation and soils.

Habitats are generally referred to by:
- land surface;
- dominant plant taxon (taxa);
- dominant vegetation structure.

They are described within the habitat groups in terms of:
- general information (physical environment, distribution patterns, general ecology);
- vegetation physiognomy and composition (by strata);
- patterns of variation (including the impact of grazing and fire);
- nature conservation status;
- gradational associations;
- land system representation.

Terminology used to describe vegetation structure

The following definitions have been used to discuss vegetation structure:

Tree: A plant over 2 m high with a single trunk to at least 1.3 m, including single trunk eucalypts

Mallee: A multi–stemmed eucalypt

Tall shrub: A plant over 2 m tall with more than one main branch below 1.3 m

Mid shrub: A shrub between 1 and 2 m in height

Low shrub: A shrub lower than 1 m in height

Perennial grass: A grass species usually persisting for at least two years

Dominant species are those which were recorded as dominant in a stratum at a third or more of sampling sites. Common species are those subordinate species recorded at a third or more sampling sites or where traverse notes indicated that they were common in the particular habitat.

Taxonomic conventions

The plant taxonomy used is based largely upon the latest supplement to Green (1985) which is Number 7, dated November 1988. Upon advice from Western Australian Herbarium Botanist, Mr Ray Cranfield, more recent taxonomic revisions not yet included in a supplement have been adopted (e.g. *Cassia* to *Senna*).

Species conservation status has been assigned according to the 'Declared Rare and Priority Flora List for Western Australia' (Department of Conservation and Land Management, unpublished list February 1994):

DRF: Declared Rare Flora – Extant Taxa

Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

P1: Priority One – Poorly Known Taxa

Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc. or the plants are under threat, e.g. from disease, grazing by feral animals etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

P2: Priority Two – Poorly Known Taxa

Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

P3 Priority Three – Poorly Known Taxa

Taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora' but are in need of further survey.

P4: Priority Four – Rare Taxa

Taxa which are considered to have been adequately surveyed and which whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5 to 10 years.

Assessment of grazing impacts

Grazing impacts are considered in recognition of their widespread influence on the native plants and animals and their habitats in this region.

The 'habitat' classification used in this chapter allows for and is the basis of consideration of grazing impacts. The classification reduces natural variation into a manageable number of ecological types within which there is strong similarity. Four major habitats were sampled specifically (at condition sites) to investigate grazing related variation. These will augment similar studies in other major habitats in previous rangeland surveys in the mulga region. The habitats sampled in this manner are:

SGRS: Sandy granitic acacia shrubland

BCLS: Breakaway footslope chenopod low shrubland

MUBW: Hardpan plain mulga and bowgada shrubland or woodland

SBMS: Stony plain bluebush mixed shrubland

These investigations consider attributes such as projected foliar cover (PFC), species composition and ecological indicator variables grounded in traditional research and assessment of grazing impacts dating to Dyksterhius (1949).

Species indicator values include:

Decreaser: Species whose abundance in a community decreases in response to increasing grazing pressure. These are palatable species that are sensitive to grazing management. In strictly grazing parlance they are 'desirables'.

Increaser: These species increase in abundance in response to increasing grazing pressure. They are often unpalatable and may be secondary invader species. They have also been termed 'undesirables' or 'woody weeds'.

Intermediates: These palatable species may increase in abundance to a certain level of grazing pressure, but being palatable they eventually decline as grazing pressure is increased. These species are often recruited into niches vacated by decreaser species.

No indicator value: The abundance of these species is not primarily related to grazing history. They are not usually very palatable and have been termed 'stability desirables' in recognition of the role they may play in maintaining soil stability and ecosystem function.

Key decreasers (KD) and key increasers (KI) are denoted in stratum species lists to support future range assessments or monitoring.

Multivariate analytical tools have been applied to summarise and describe botanical variation in these four major habitats. The applicability of ecological models and theories such as ecological succession (Clements 1916, Dyksterhius 1949, Sampson 1917) and the State and Transition model (Westoby *et al.* 1989) at the sampling scale are mentioned. This information will provide an overview of ecological variation which can then be interpreted for future land use and land management planning, as well as providing indicators and models for future resource monitoring.

In a broadscale survey such as this, it is difficult to establish linkages with scientific rigour between disturbances such as grazing and ecological variation (except where very obvious, such as a recently burnt area). It is therefore important to appreciate that many of the interpretations are based on the experience of the assessors and their ability to recognise and explain signs of impact. Substantial data were collected and analysed in previous surveys for major habitats found in this survey area, including surveys of the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a). This information is summarised under relevant habitat descriptions to augment information collected during this survey.

This chapter in context

This chapter focuses on habitat and plant community description and ecology. At a broader scale, landscape characteristics are covered in the geomorphology and land system chapters. Summaries of visual traverse assessments of resource condition are presented in the resource condition chapter.

Description of habitats within their broader groups

Fifty major habitats split into 10 habitat groups (Table 1) are described in some detail. A further 13 habitats sampled less than four times are mentioned briefly.

A. HILL, RIDGE AND BREAKAWAY PLATEAU SCLEROPHYLL SHRUBLAND AND WOODLAND HABITATS

High in the landscape, these habitats differ considerably reflecting the influence of rock substrate on soil characteristics. This is one of the few examples in the survey area where underlying substrate is a primary influence on species composition. Elsewhere, soils are largely deposits of regional sediments which have little association with the rocks underneath, which results in a small number of species associations related primarily to sediment characteristics (e.g. chenopods on saline alluvium).

Sclerophylly (leathery leaves) is the dominant feature of vegetation in these highest parts of the landscape. This reflects base–deficiency (e.g. low calcium and sodium concentrations) and lack of water retention capacity in the soil, which is characteristic of many uplands. Soils are often limited to pockets of detrital material indicative of very slow weathering processes and effective erosion. Secondary induration of rocks provides a surface layer impervious to water which further retards weathering and soil development.

Given that these habitats often have a distinctive flora and occur largely as isolated areas high in an old, flattened landscape, they have disproportionately high flora

Table 1. Habitat groups and their component habitats

A.	Hill, ridge and breakaway plateau sclerophyll shrubland or woodland habitats	
1.	BRXS	Breakaway mixed shrubland
2.	GHAS	Greenstone hill acacia shrubland
3.	GHMW	Greenstone hill mixed woodland or shrubland
4.	GRHS	Granite hill mixed shrubland
5.	SIAS	Stony ironstone acacia shrubland
6.	SIMS	Stony ironstone mulga shrubland
7.	UFTH	Upland fringing thicket
	IRMS	Ironstone ridge mixed shrubland
B.	Stony plain and low rise sclerophyll shrubland habitats	
8.	GABS	Granitic acacia Borya shrubland
9.	SAES	Stony acacia eremophila shrubland
10.	SGRS	Sandy granitic acacia shrubland
	GMAS	Granitic melaleuca acacia shrubland
C.	Stony plain and low rise chenopod shrubland (and occasional woodland) habitats	
11.	BCLS	Breakaway footslope chenopod low shrubland
12.	BECW	Breakaway footslope eucalypt woodland with chenopod understorey
13.	SBMS	Stony plain bluebush mixed shrubland
14.	USBS	Upland small bluebush species shrubland
	SSMS	Stony saltbush mixed shrubland
D.	Alluvial plain with conspicuous chenopod shrubland (and occasional woodland) habitats	
15.	ASWS	Alluvial plain snakewood chenopod shrubland
16.	BLSS	Bladder saltbush low shrubland
17.	GGLS	Gilgai grassy low shrubland
18.	PECW	Plain eucalypt chenopod woodland
19.	PYCW	Plain York gum chenopod woodland
20.	PSAS	Plain sago bush shrubland
21.	PXHS	Plain mixed halophyte shrubland
22.	SAMP	Samphire flat
23.	SBLS	Sandy bank lake shrubland
24.	SSAS	Silver saltbush shrubland
25.	DACS	Drainage tract acacia shrubland/woodland with chenopod understorey
	FRAN	Frankenia low shrubland
	MHHS	Mixed chenopod shrubland with mulga overstorey
	POMS	Plain oldman saltbush shrubland
E.	Calcrete or kopi associated shrubland or woodland habitats	
26.	CAPW	Calcrete platform woodland
27.	JAMS	Calcrete platform jam shrubland
	CCAS	Calcareous casuarina acacia shrubland or woodland
	KOPI	Kopi dune or plain woodland
F.	Drainage focus sclerophyll habitats	
28.	MESS	Melaleuca swamp shrubland
29.	ACGU	Acacia with claypan grass understorey
	PDFT	Plain drainage focus thicket
	CGSW	Cane grass swamp
	LISW	Lignum swamp
G.	Broad sheet flood hardpan plain sclerophyll shrubland or woodland habitats	
30.	HPMS	Hardpan plain mulga shrubland
31.	HCAS	Hardpan plain acacia shrubland
32.	HMCS	Hardpan plain mulga shrubland with scattered chenopods
33.	DRAS	Drainage tract acacia shrubland
34.	CBKW	Creek bank woodland or shrubland
35.	GRMU	Hardpan plain mulga grove
36.	LHMS	‘Lateritic’ hardpan plain mulga shrubland

Table 1. continued . . .

37.	MUBW	Hardpan plain mulga and bowgada shrubland or woodland
38.	WABS	Wanderrie bank grassy mulga shrubland
	CBBS	Creekline bottlebrush shrubland
H.	Plains transitional to sandplain with sclerophyll shrubland or woodland habitats	
39.	PYAW	Plain York gum acacia woodland
40.	PINW	Plain native pine acacia woodland or shrubland
41.	PLMS	Plain sandy loam mulga shrubland
42.	MUWA	Mulga wanderrie grassland or shrubland
I.	Sandplain hummock grassland habitats	
43.	SASP	Sandplain spinifex hummock grassland
44.	SAMU	Sandplain mulga spinifex hummock grassland
J.	Sandplain sclerophyll shrubland habitats	
45.	SWGS	Sandplain grassy bowgada shrubland
46.	SACS	Sandplain acacia shrubland
47.	LACS	Lateritic sandplain acacia shrubland
48.	LSHE	Lateritic sandplain heath
49.	SCMS	Sandplain close mixed shrubland
50.	MAAS	Sandplain with mallees and acacias
	SDSH	Sand dune shrubland

conservation value. They co–incidentally have relatively low pastoral value and stock preference and are probably threatened more by feral goats than stock. Mining is another threat, particularly in the greenstone domain.

This sparse sclerophyll shrubland dominated by acacias on a ridge in Gabanintha land system (SIMS habitat) is typical of this habitat group. Soils are shallow and stony on these ridge slopes, run-off accounts for most rainfall and primary productivity is very low, even for this region.

1. Breakaway mixed shrubland (BRXS)

Sampling 20 inventory sites and numerous ad hoc searches for unusual flora

General information

BRXS is most common as stripped pebbly plateau surfaces between sandplain and breakaway scarps in granite-dominated terrain. These plateaux result from the oxidation of mobile iron to form a resistant layer or cap over softer, decomposing rock. Breakaway edges collapse when the scarp face of softer material erodes back under the resistant cap. It is not known how rapidly this process occurs.

It is distributed throughout the survey area as narrow bands in erosional landscapes and as pockets of exposed stripped surfaces in extensive areas of sandplain, as occur on the Barlee map sheet. It was also described in the adjacent north–eastern Goldfields survey to the east (Pringle 1994a).

Physiognomy and composition of vegetation

BRXS generally occurs as very scattered to scattered (2.5–10% projected foliar cover) low shrubland, occasionally a tall shrubland and usually has a clearly recognisable mid shrub stratum. Approximately 130 perennial species were recorded at the 20 inventory sites, with an average of 16 species per site, near the survey average. Thirteen species were recorded only at BRXS sites and a further 12 were recorded only at BRXS sites and in one other habitat. Species exclusive to BRXS sites that were recorded more than once include *Calytrix desolata, Micromyrtus sulphurea* and *Xerolirion divaricata.*

The following species (by strata) are dominant and/or common:

Tall shrubs: Dominant – occasionally *Acacia aneura* or *A. quadrimarginea*.
Common – *Acacia acuminata* subsp. *burkittii, A. ramulosa.*

Mid shrubs: Dominant – occasionally *Acacia ramulosa*, *Thryptomene decussata* or *T. mucronulata*.
Common – *Eremophila latrobei* (KD).

Low shrubs:	Dominant – very variable, including *Eriostemon brucei, E. sericeus, Micromyrtus sulphurea, Prostanthera* spp. *Ptilotus obovatus, Thryptomene* spp. Common – *Eremophila latrobei* (KD), *Ptilotus schwartzii* (KD), *Sida calyxhymenia, Solanum lasiophyllum.*
Perennial grasses:	Dominant – nil. Common – *Stipa elegantissima*.
Other common plants:	*Borya sphaerocephala* (resurrection plant), *Cheilanthes austrotenuifolia* (fern).

Patterns of grazing impact

Long-term grazing impacts involve the removal of palatable shrub species such as *Eremophila latrobei, Sida calyxhymenia, Ptilotus obovatus* and *P. schwartzii*. However, their absence is as likely to reflect natural variability. Soil erosion is not generally a land management hazard.

Nature conservation

This habitat supports a disproportionately high number of Declared Rare and Priority Species (see also Pringle 1994a,b). These include *Calytrix verruculosa* (P1), *Grevillea erectiloba* (P4), *Leucopogon breviflorus* (P2) and *Prostanthera magnifica* (DRF). These species are not generally grazed by stock and it is not known whether goats graze them. Breakaway footslopes generally support preferentially grazed species and to some extent divert grazing pressure from areas of BRXS upslope. Although adjacent spinifex communities are highly flammable, there is usually a sharp boundary between these habitats and ephemeral growth is unlikely to accumulate enough fuel to support a fire in these scattered shrublands.

Gradational associations

BRXS generally has sharp boundaries defined by the scarp face of breakaways (downslope of which are chenopods), and away from the scarp by sandplain with close acacias and/or spinifex grassland. In floristic terms, BRXS is most similar to *Ironstone ridge mixed shrubland* (IRMS), whose rock is also iron-enriched.

Land systems

Challenge, Euchre, Nerramyne, Sherwood and Waguin, less frequent in Joseph and Kalli.

2. Greenstone hill acacia shrubland (GHAS)

Sampling 15 inventory sites

General information

GHAS occurs on greenstone hills scattered in belts through the survey area. Soils are generally shallow and stony and support sclerophyll shrubland dominated by acacias other than A. aneura, which is the most common dominant acacia in the survey area. GHAS occurs throughout the survey area, but is replaced to some extent by eucalypts and Casuarinaceae in the south. It was also described in the adjacent north-eastern Goldfields survey (Pringle 1994a).

Physiognomy and composition of vegetation

GHAS consists generally of very scattered to scattered (5–15% projected foliar cover) tall shrubland, occasionally with a dominant or co–dominant low shrub stratum. Mid shrubs sometimes form a recognisable stratum, however trees and perennial grasses are usually a minor component, if present. Approximately 80 perennial species were recorded at the 15 GHAS inventory sites, at an average of 14 per site, below the survey average of 16. The flora is not particularly characteristic; most species are common elsewhere.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – rarely *Casuarina pauper* or *Eucalyptus concinna*. Common – nil.
Tall shrubs:	Dominant – *Acacia quadrimarginea*, occasionally *A. acuminata* subsp. *burkittii*, rarely other acacias. Common – *Acacia tetragonophylla, Santalum spicatum.*
Mid shrubs:	Dominant – variable, acacias and *Senna* spp. Common – *Senna artemisioides* subsp. *sturtii, Rhagodia eremaea*.
Low shrubs:	Dominant – usually *Ptilotus obovatus.* Common – *Senna artemisioides* subsp. *artemisioides, S. artemisioides* subsp. *sturtii, Maireana planifolia, Solanum lasiophyllum*.
Perennial grasses:	Dominant – occasionally facultative biennial *Enneapogon* or *Stipa* spp.

Patterns of grazing impact

GHAS is not preferred for stock; there is generally more palatable forage downslope. In overgrazed situations one might expect a decline in species such as *Maireana* spp. (e.g. *M. planifolia*) and *Ptilotus obovatus*. The abundance of *P. obovatus* appears to be heavily influenced by recent seasons and is naturally highly spatially variable. GHAS is not generally susceptible to soil erosion unless protective stone mantles are disturbed.

Nature conservation

Grevillea inconspicua, listed in the Declared Rare Flora, occurs in GHAS. Part of a population on Lake Mason station has been exclosed in a Sandstone Land Conservation District Committee project supported by the Western Australian Department of Conservation and Land Management and Agriculture Western Australia. The project is in an historically severely degraded part of the station and yet, while obviously grazed, unexclosed plants remain vigorous. It is uncertain however, whether *G. inconspicua* can recruit new adult plants without the removal of the grazing pressures of stock and feral goats (and possibly kangaroos). In the

north–eastern Goldfields, a number of unusual acacias, possibly of conservation priority, were recorded (Pringle 1994b). It is likely that the situation applies also to this adjacent area.

Gradational associations

GHAS often grades downslope into *Stony ironstone mulga shrubland* (SIMS), as *Acacia aneura* succeeds other acacias as the dominant tall shrub.

Land systems

Gabanintha, Naluthanna and Singleton.

3. Greenstone hill mixed woodland or shrubland (GHMW)

Sampling 13 inventory sites

General information

GHMW occupies a similar part of the landscape – greenstone hills and ridges – to GHAS, but has denser, more structurally complex vegetation including trees. It occurs on shallow, sometimes calcareous, stony soils.

While GHAS is typical of the Eremaean Botanical Province (Beard 1991), GHMW represents the mixed dry woodlands of the South-Western Interzone and is most common in the far south–east of the survey area, south of Lake Barlee. While GHMW occurs to the east of the Menzies 1:250,000 scale map sheet, it was not considered extensive enough to describe in its own right in the north-eastern Goldfields rangeland survey (Pringle 1994a), although GHMW includes eucalypt communities previously described as *Greenstone hill (non-halophytic) eucalypt woodlands* (GNEW).

Physiognomy and composition of vegetation

GHMW varies from scattered to close (10–50% projected foliar cover) woodlands or tall shrubland. The low shrub stratum is usually well developed.

Ninety–seven perennial species were recorded at the 13 sites, at an average of 15 species per site, marginally below the survey average. Ten perennial species were found only in GHMW and a further three also in only one other habitat. *Eriachne aristidea*, *Eucalyptus ebbanoensis* and *Grevillea georgeana* were each recorded twice and only in GHMW.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – variable; *Allocasuarina* spp., *Casuarina pauper* and occasionally *Eucalyptus* spp. Only *Casuarina pauper* occurred at more than a third of sites.
Tall shrubs:	Dominant – variable; usually *Acacia* species. Common – *Acacia aneura, A. acuminata* subsp. *burkittii, A. tetragonophylla.*
Mid shrubs:	Dominant – none dominant at 2 sites. Common – *Scaevola spinescens*.
Low shrubs:	Dominant – *Ptilotus obovatus* at more than half (7) of the sites. Common – *Prostanthera althoferi, Scaevola spinescens*.
Perennial grasses:	Dominant – nil. Common – *Stipa elegantissima*.
Other common plants:	*Dianella revoluta* (lily).

Patterns of grazing impact

It is likely that palatable perennial species such as *Ptilotus obovatus* can be removed by excessive grazing of the understorey, perhaps with a concomitant increase in species such as *Senna artemisioides* subsp. *filifolia* and *Dodonaea lobulata*. Stone mantles generally provide effective protection against erosion.

Nature conservation

GHMW incorporates some species with recognised conservation value including *Acacia 'kalgoorliensis'* (MS), *Allocasuarina tessellata, Grevillea georgeana, Leucopogon* aff. *breviflorus* and *Prostanthera magnifica* (DRF). *Dryandra arborea*, a proteaceous tree occurs as scattered outlier populations at the north–eastern limit of its distribution in the south–eastern quadrant of the Barlee 1:250,000 scale map sheet.

There is little evidence to suggest that grazing by stock threatens flora conservation values in this habitat, uncontrolled feral goat populations are likely to pose a considerably greater threat.

Gradational associations

GHMW habitats, while variable, generally have reasonably well defined boundaries, which tend to be dominated by species more common and extensively distributed in the area.

Land systems

Dryandra, Moriarty, Mulline and Singleton.

4. Granite hill mixed shrubland (GRHS)

Sampling 8 inventory sites

General information

GRHS occurs on and around large exposures of granite, in the form of domes or tor fields. It does not include the fringing thicket drainage foci commonly associated with these outcrops, which are treated as a separate habitat (UFTH). The rocks represent residuals more resistant to weathering and subsequent erosion than in surrounding plains, which have been eroded and are now largely covered in alluvial and colluvial deposits. 'Soil' is limited to pockets of coarse detrital grit from the breakdown of pieces of granite

dislodged by ‘onion skin’ weathering. GRHS often provides the most impressive vistas and tourist attractions in an area.

It was previously described in the adjacent north–eastern Goldfields survey to the east (Pringle 1994a) and occurs in most parts of this survey area.

Physiognomy and composition of vegetation

Vegetation structure varies considerably in response to the amount of rock exposed (with foliose lichens on it) and the degree of development of minor drainage areas and piles of rock debris. They support very scattered to scattered (2.5–15% projected foliar cover) tall or mid shrubland, often with a recognisable low shrub stratum. Perennial grasses rarely form a recognisable stratum and trees are usually isolated individuals.

Nearly 70 perennial species were recorded at the eight GRHS sites which averaged 16 per site, the survey average. Four perennial species were only recorded in GRHS and five were also recorded in only one other habitat. *Cheilanthes lasiophylla* was the only one of these species recorded more than once (three records).

The following species (by strata) are dominant and/or common:

Trees:	Dominant – none. Common – *Brachychiton gregorii*.
Tall shrubs:	Dominant – *Acacia quadrimarginea*. Common – *Acacia aneura, A. tetragronophylla*, *Dodonaea viscosa* subsp. *viscosa*, *Eremophila platycalyx*.
Mid shrubs:	Dominant – various *Eremophila* spp. e.g. *E. exilifolia, E. latrobei, E. platycalyx.* Common – *Eremophila exilifolia, E. forrestii, E. latrobei, E. platycalyx, Thryptomene mucronulata*.
Low shrubs:	Dominant – highly variable, most commonly *Eremophila exilifolia*. Common – *Eremophila exilifolia, E. latrobei (KD), Ptilotus obovatus, Sida calyxhymenia, Solanum horridum, S. lasiophyllum*.
Perennial grasses:	Dominant – occasionally *Cymbopogon ambiguus*. Common – *Cymbopogon ambiguus*.
Other common plants:	*Borya sphaerocephala* (resurrection plant), *Cheilanthes austrotenuifolia* (mulga fern), *C. lasiophylla* (rock fern).

Patterns of grazing impact

GRHS is not a preferred grazing habitat for stock; kangaroos and feral goats are most probably responsible for most grazing. Presumably palatable perennial species such as *Eremophila forrestii, E. latrobei*, *Ptilotus obovatus* and *Sida calyxhymenia* can be removed under excessive grazing. Soil erosion is not generally a hazard.

Nature conservation

Prostanthera magnifica was recorded at one inventory site. Feral goats are often encountered, possibly using these areas as refugia during control programs such as mustering and helicopter shooting.

Gradational associations

This is a distinctive habitat which generally has clearly defined boundaries.

Land systems

Challenge, Norie and Olympic.

5. Stony ironstone acacia shrubland (SIAS)

Sampling 30 inventory sites

General information

SIAS is the southern equivalent of *Stony ironstone mulga shrubland* (SIMS) habitat described below, but has a generally denser, more variable upperstorey. Both SIAS and SIMS occur on the slopes of hills, ridges and rises in the greenstone-dominated uplands, including ridges of banded iron formation. SIAS was not sampled on the Sandstone 1:250,000 scale map sheet and was only sampled at three sites on the Youanmi and Kirkalocka map sheets, which are also largely dominated by A. aneura (mulga). Soils are generally shallow and stony, sometimes having lenses of calcrete or lines of silt which indicate underlying variability in the bedrock.

Physiognomy and composition of vegetation

SIAS habitats normally consist of a scattered to moderately close (15–30% projected foliar cover) tall shrubland commonly with recognisable mid and low shrub strata. Tree and perennial grass components are not generally conspicuous.

About 160 perennial species were recorded at 30 inventory sites, at an average of 17 species per site, slightly above the survey. Twelve species were only recorded in SIAS and a further 15 only recorded in one other habitat. *Eremophila glutinosa* and *Hemigenia macphersonii* were the only two with multiple records (two each).

The following species (by strata) are dominant and/or common:

Trees:	Dominant – no species recorded as dominant twice, however, 3 *Acacia* spp. and 2 each of the genera *Casuarina* and *Eucalyptus* were recorded (7 tree strata recognised at 30 sites). Common – none.
Tall shrubs:	Dominant – *Acacia ramulosa*, less frequently *Acacia acuminata* subsp. *burkittii, A. quadrimarginea*. Common – *Acacia aneura, A. acuminata* subsp. *burkittii, A. quadrimarginea, A. tetragonophylla, Santalum spicatum.*
Mid shrubs:	Dominant – very variable, 17 different species recorded at 30 sites. Common – *Eremophila forrestii, Scaevola spinescens.*

Low shrubs:	Dominant – very variable, sometimes *Ptilotus obovatus* (10 of 30 sites). Common – *Senna artemisioides* subsp. *filifolia, Eremophila forrestii, E. latrobei* (KD), *Eriostemon brucei, Ptilotus obovatus, Scaevola spinescens, Sida virgata, Solanum lasiophyllum.*
Perennial grasses:	Dominant – 4 species recorded once each. Common – *Stipa elegantissima.*
Other common plants:	*Cheilanthes austrotenuifolia* (mulga fern) and *Dianella revoluta* (lily).

Patterns of grazing impact

SIAS is not particularly attractive to stock as many of its perennial species are unpalatable. Given the high proportion of unpalatable perennials, it is unlikely that stock would alter the fundamental structure of vegetation. This habitat has stable soil surfaces, at least when perennial shrub cover is maintained.

Nature conservation

Grazing by stock appears not to threaten this habitat's vegetation. Feral goats may pose a threat. *Acacia speckii* (P3) and *Grevillea inconspicua* (DRF) were each collected once.

Gradational associations

SIAS may grade downslope into *Hardpan close acacia shrubland* (HCAS) on alluvial tracts, but generally has clearly defined boundaries at the change of slope into lower plains.

Land systems

Gabanintha, Illaara, Moriarty, Mulline, Naluthanna, Tallering, Watson and Wiluna.

6. Stony ironstone mulga shrubland (SIMS)

Sampling 29 inventory sites

General information

SIMS occurs on the hillslopes and low rises in greenstone-dominated terrain. It often has a heavy stone mantle of rocks which have been secondarily indurated by iron and may include limonite. Soils are generally shallow red earths on greenstone, basalt, jaspilite or occasionally felsic metamorphic rocks.

It was most frequent in the north–east and rarely seen in the south–west, a pattern opposite to SIAS described above and with which it is most similar. The species of *Acacia* and denser cover in SIAS possibly reflect better, more reliable, winter seasons.

Physiognomy and composition of vegetation

SIMS generally consists of very scattered to scattered (5–25% projected foliar cover, most frequently 10–20%) tall shrubland with a well developed low shrub stratum and a recognisable mid shrub stratum. Trees and perennial grasses, when present, are generally not a major component.

One hundred and thirty perennial plant species were recorded at the survey average of 16 per inventory site. Seven species were only recorded in SIMS habitat and a further seven occurred only in one other habitat. Of these species, only *Canthium latifolium* and *Eremophila punctata* were recorded twice.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – none. Common – *Acacia aneura.*
Tall shrubs:	Dominant – most frequently *Acacia aneura* (18 of 29 sites), otherwise other *Acacia* spp. Common – *Acacia acuminata* subsp. *burkittii, A. quadrimarginea, A. ramulosa, A. tetragonophylla* and less frequently, *Santalum spicatum*.
Mid shrubs:	Dominant – very variable, 12 species recorded, many *Acacia* or *Eremophila* spp. Common – *Eremophila forrestii, E. latrobei* (KD), *Rhagodia eremaea, Scaevola spinescens, Sida calyxhymenia.*
Low shrubs:	Dominant – often *Ptilotus obovatus,* also *Eremophila* or *Maireana* spp. Common – various *Senna* spp. (none in particular), *Dodonaea microzyga, Eremophila forrestii, E. latrobei* (KD), *Eriostemon brucei, Maireana convexa* (KD), *M. georgei* (KD), *M. triptera, Ptilotus schwartzii* (KD), *Rhagodia eremaea, Scaevola spinescens, Sida calyxhymenia, Solanum lasiophyllum.*
Perennial grasses:	Rarely present.
Other common plants:	*Cheilanthes austrotenuifolia* (mulga fern).

Patterns of grazing impact

SIMS was found to have naturally highly variable palatable low shrub composition and density in the adjacent north–eastern Goldfields survey (Pringle 1994a). However, some of the following palatable species should be present: *Eremophila latrobei, Maireana convexa, M. georgei, Ptilotus obovatus, P. schwartzii* and *Sida calyxhymenia.* Sites devoid of any of these plants may confidently be assumed to have been substantially altered by grazing.

Stone mantles and an unpalatable dominant tall shrub stratum give considerable soil stability.

Nature conservation

SIMS is not preferentially grazed, however escalations in feral goat numbers are likely to lead to degradation. No plant species of specific conservation priority were recorded.

Gradational associations

SIMS grades downslope into either *Stony acacia eremophila shrubland* (SAES) or *'Lateritic' hardpan plain mulga shrubland* (LHMS) and occasionally upslope into *Greenstone hill acacia shrubland* (GHAS).

Land systems

Bevon, Brooking, Gabanintha, Hootanui, Naluthanna, Nubev, Teutonic, Violet, Wiluna and Yarrameedie.

7. Upland fringing thicket (UFTH)

Sampling 7 inventory sites

General information

Most UFTH habitats were sampled in the southern half of the survey area adjacent to substantial granite outcrops or breakaways. Habitats range from 20 to 50 m across, often reflecting the amount of run-on captured from adjacent rock outcrops.

These habitats represent fertile patches in a largely harsh landscape, reflected in good soil cryptogam development and the abundance of invertebrates such as ants and centipedes. The flora is usually quite different from surrounding plains and may include very attractive flowering species such as *Kunzea pulchella*. Soils generally consist of coarse detrital matter washed off outcrops, with noticeable dark colouring from accumulation of organic matter.

Physiognomy and composition of vegetation

UFTH supports moderately close tall shrubland to close thickets (25 to nearly 100% projected foliar cover) with subordinate low and mid shrub understoreys. Approximately 70 species were recorded at seven inventory sites, at an average of 19 species per site. Given that this habitat's usually spatial restriction to small drainage foci, this is a high level of species richness for the area. Four species were only recorded at UFTH sites and two more were recorded at only one other site, however *Gastrolobium laytonii* is the only one of these species recorded twice. The floristic composition varies markedly around large outcrops as well as between outcrops. No individual species consistently dominated any stratum.

The following species (by strata) were common:

Trees:	*Eucalyptus loxophleba, Melaleuca uncinata.*
Tall shrubs:	*Acacia acuminata subsp. burkittii, A. quadrimarginea, A. ramulosa, A. tetragonophylla, Calycopeplus ephedroides, Gastrolobium laytonii, Hakea recurva, Kunzea pulchella, Melaleuca uncinata, Santalum spicatum.*
Mid shrubs:	*Alyxia buxifolia, Senna glutinosa subsp. charlesiana, Dodonaea inaequifolia, Eremophila forrestii, E. latrobei* (KD), *Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	*Senna artemisioides subsp. filifolia, S. artemisioides subsp. petiolaris, Enchylaena tomentosa, Eremophila clarkei, E. exilifolia, E. forrestii, E. latrobei* (KD), *Maireana planifolia, M. thesoides, Olearia pimelioides, Rhagodia drummondii, R. eremaea, Scaevola spinescens, Solanum lasiophyllum.*
Perennial grasses:	*Stipa elegantissima.*

Patterns of grazing impact

Not much is known. Presumably palatable understorey species could be removed under excessive grazing pressure. These include *Enchylaena tomentosa, Eremophila latrobei* and *Maireana* spp. Such is the natural variability in this habitat's flora, it is difficult to confidently assess grazing impacts. In most cases the dominant plants are not particularly palatable or preferred by stock.

Nature conservation

No plant species of known conservation priority were collected, however species richness, distinctly different flora to adjacent communities and limited distribution, give it conservation importance. It is not known what impact pastoral management and the introduction of feral carnivores (cats and foxes) and herbivores (goats and rabbits) have had on this habitat's fauna, both by predation and modification of habitat. Large areas may act as drought refugia for fauna.

Gradational associations

UFTH occurs as discreetly defined fertile patch habitats in otherwise largely infertile upland landscapes and bears little resemblance to other habitats.

Land systems

Challenge, Euchre, Norie, Olympic and Waguin.

Other minor habitats in 'hill, ridge and breakaway plateaux sclerophyll shrubland and woodland habitat' group

Ironstone ridge mixed shrubland (IRMS) – 2 inventory sites

IRMS occurs in the south and west of the survey area and supports a distinctive flora associated with the South-West Botanical Province. The low shrub stratum is usually dominant or co–dominant with either mid or tall shrubs. It is the most species-rich habitat in the survey area with 41 species recorded at two sites at an average of 25 species each. *Eriostemon sericeus* was the common dominant low shrub and *Thryptomene decussata* was its mid shrub counterpart.

B. STONY PLAIN AND LOW RISE SCLEROPHYLL SHRUBLAND HABITATS

These habitats are almost exclusive to granite-dominated upland terrain, occurring downslope of major outcrop habitats on etchplains grading downslope into alluvial plains with substantial stony mantles. The vegetation is generally dominated by sclerophyllous and/or Eremaean genera including *Acacia, Senna, Eremophila* and *Ptilotus*, usually occurring as very scattered to scattered tall shrubland with easily recognisable, though sparse understoreys and occasional trees.

This gritty-surfaced plain in Challenge land system (SGRS habitat) characteristically supports a scattered acacia tall shrub layer with sparse understorey shrubs. In this case, Ptilotus obovatus *(cotton bush) is the common low shrub found growing between areas of exposed granite. The ground layer is often dominated by* Aristida contorta *(windgrass) after substantial rains.*

8. Granite acacia Borya shrubland (GABS)

Sampling 9 inventory sites

General information

GABS is almost entirely restricted to the south-west of the survey area adjacent to the wheatbelt region. It is similar to *Sandy granitic acacia shrubland* (SGRS) described below, representing a regional variation grading away from the Eremaean Zone into the South-West Botanical Province of Beard (1991). Vegetation cover is sometimes greater in GABS than SGRS and *Borya sphaerocephala* (resurrection plant) is distinctive. Soils are shallow (<30 cm deep) coarse red sands between low (usually <2 m high) granite outcrops.

Physiognomy and composition of vegetation

GABS usually consists of scattered to moderately close (15–30% projected foliar cover) tall shrubland where Borya *sphaerocephala* mats were not dominant. Trees and perennial grasses are not well represented in this relatively infertile habitat.

Seventy species were recorded at an average of 18 per site, a little over the survey average. Most species were common in other habitats.

The following species (by strata) were dominant and/or common:

Trees:	None common.
Tall shrubs:	Dominant – variable; *Acacia acuminata* subsp. *burkittii, A. quadrimarginea* or *A. tetragonophylla.* Common – *Acacia acuminata* subsp. *burkittii, A. grasbyi, A. quadrimarginea, A. ramulosa, A. tetragonophylla, Eremophila platycalyx, Melaleuca uncinata.*
Mid shrubs:	Dominant – *Thryptomene mucronulata.* Common – *Senna glutinosa* subsp. *charlesiana, Eremophila eriocalyx, E. latrobei* (KD), *E. platycalyx.*
Low shrubs:	Dominant – variable, sometimes *Grevillea pityophylla* or *Ptilotus obovatus.* Common – *Senna artemisioides* subsp. *petiolaris, Enchylaena tomentosa* (KD), *Eremophila latrobei* (KD), *Grevillea pityophylla, Ptilotus obovatus, P. schwartzii, Sida virgata, Solanum lasiophyllum.*
Perennial grasses:	Dominant – none recorded. Common – *Stipa elegantissima.*
Other commonly dominant plants:	*Borya sphaerocephala* (resurrection plant).
Other common plants:	*Cheilanthes austrotenuifolia* (mulga fern).

Patterns of grazing impact

Such is the natural variability in these sites, it is not possible to define realistic range classes. Instead, indicator species are proposed which, if monitored, will provide some idea of grazing impact trends (range trend). Palatable indicator species include *Enchylaena tomentosa*, *Eremophila latrobei* and *Ptilotus schwartzii.* Large fluctuations in *Ptilotus obovatus* numbers may more closely reflect seasonal influences than management impacts and this species abundance is characteristically very variable spatially (Pringle 1994a). Soils appear to be inherently stable.

Nature conservation

While no priority species for nature conservation were recorded, the vegetation is distinctive and contains numerous species not widely distributed in the area. Beard (1991) recognises the importance of granite outcrops for flora conservation in the adjacent wheatbelt, where *Borya sphaerocephala* is accompanied by rare plants (e.g. *Eucalyptus caesia*).

Gradational associations

GABS is a distinctive habitat which usually has clearly defined boundaries.

Land systems

Bandy, Challenge, Euchre, Joseph, Nerramyne, Olympic and Yowie.

9. Stony acacia eremophila shrubland (SAES)

Sampling 18 inventory sites, 1 condition site

General information

SAES occurs as nearly level stony plains below areas of greater relief in both greenstone and granite-dominated landscapes. These plains usually extend further downslope from areas of outcrop in granitic than greenstone landscapes. This reflects the prominence of granitic rocks in the Yilgarn Craton as opposed to the narrow 'belt' configuration of greenstone and allied rocks. To the north and east of this survey area, SAES is the most widespread erosional plains habitat (Curry *et al.* 1994, Pringle *et al.* 1994). In this survey, gritty surfaced plains with granite exposures (GABS and SGRS) predominate.

Soils are generally shallow (<60 cm) stony red earths and occasionally sands, formed by the deposition of alluvial and colluvial material. SAES is a typically Eremaean habitat, which is reflected in its almost total confinement to the three north–eastern map sheets of the survey area: Kirkalocka, Youanmi and Sandstone.

Physiognomy and composition of vegetation

SAES generally occurs as very scattered to scattered (5–20% projected foliar cover) tall or low shrubland with a well developed mid shrub stratum. Trees and perennial grasses are not usually conspicuous. Seventy–five species were recorded at the 18 inventory sites, at an average of 14 per site, slightly lower than the survey average. Flora consists largely of species found in numerous other habitats.

The following species (by strata) were dominant and/or common:

Trees:	Dominant – *Acacia aneura* occasionally recorded. Common – *A. aneura.*
Tall shrubs:	Dominant – *A. aneura.* Common – *A. quadrimarginea, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable; several *Acacia* and *Eremophila* spp. Common – *Acacia tetragonophylla, Eremophila fraseri, E. latrobei* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – very variable, 11 species recorded. Common – *Senna artemisioides* subsp. *sturtii, Eremophila fraseri, E. forrestii* (KD), *E. latrobei* (KD), *Ptilotus obovatus, P. schwartzii* (KD), *Sida calyxhymenia* (KD), *Solanum lasiophyllum, Spartothamnella teucriiflora* (KD).
Perennial grasses:	None common.
Other common plants:	*Dianella revoluta* (lily).

Nine *Acacia*, five *Senna glutinosa* subspecies, 20 *Eremophila*, 10 *Maireana* and four *Ptilotus* species were recorded.

Patterns of grazing impact

Grazing is likely to reduce the number of sensitive palatable shrub species and their densities. These include *Eremophila forrestii, E. latrobei, Maireana* spp. (e.g. *M. convexa, M. planifolia* and *M. thesioides*), *Ptilotus schwartzii, Sida calyxhymenia* and *Spartothamnella teucriiflora*. While species such as *E. forrestii* and *S. calyxhymenia* are resilient to heavy grazing, under such conditions their ability to recruit juveniles may be effectively suppressed. More sensitive species such as *M. convexa* are killed by excessive grazing and hence indicate change more rapidly.

Care should be taken when assessing grazing impacts, as natural variation can be as influential as management on botanical composition (Pringle 1994a).

Nature conservation

This is very extensive in the Eremaean Zone, rarely supports priority species for conservation and consists mostly of species with wide environmental affinities. It occurs in Wanjarri Nature Reserve in the adjacent north–eastern Goldfields (Pringle *et al.* in prep, Pringle 1993, 1995b,). *Verticordia interioris* (P3) was recorded at the condition site.

Gradational associations

SAES grades downslope into *Hardpan plain mulga shrubland* (HPMS) as the *Acacia aneura* cover increases and stone mantles become sparser.

Land systems

Most extensive in Challenge, Gransal, Hamilton, Jundee, Nerramyne, Sherwood, Violet and Windarra, but present in most upland land systems.

10. Sandy granitic acacia shrubland (SGRS)

Sampling 31 inventory sites and 47 condition sites

General information

SGRS is almost entirely confined to granite-dominated landscapes and consists of very gently undulating, gritty surfaced plains with occasional rock outcrops. It is the Eremaean counterpart of GABS discussed previously. It is dominant in granite landscapes with sclerophyll vegetation, unlike further north and east, where stony plains (SAES) predominate (Curry *et al.* 1994, Pringle *et al.* 1994). SGRS

occurs throughout the survey area, but grades into and is gradually replaced by GABS in the west, adjacent to the wheatbelt. SGRS has previously been described in both the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a). SGRS was most frequently observed in the northern half of the survey area, and least often in areas dominated by sandplain and greenstone belts such as the Barlee map sheet (Figure 1).

Soils are typically pockets of very shallow (<30 cm) red clayey sands derived in situ from the breakdown of exfoliating granites and not surprisingly support highly sclerophyllous vegetation in such an infertile habitat.

Physiognomy and composition of vegetation

Vegetation usually consists of very scattered to scattered (5-20% projected foliar cover) tall shrubland, occasionally the low shrub stratum is dominant or co–dominant. A mid shrub stratum is invariably recognisable. Trees and perennial grasses are rarely conspicuous.

One hundred and fourteen species were recorded at the 31 inventory sites, at an average 15 per site; about the average. SGRS has about average species richness per site, but few species particular to it.

The following species (by strata) are dominant and/or common:

Trees:	None.
Tall shrubs:	Dominant – *Acacia quadrimarginea*, occasionally *A. aneura* or *A. acuminata* subsp. *burkittii*. Common – *A. aneura, A. acuminata* subsp. *burkittii, A. craspedocarpa, A. ramulosa, A. tetragonophylla*.
Mid shrubs:	Dominant – very variable, *Eremophila forrestii* (KD), *Thryptomene mucronulata* most common. Common – *Acacia tetragonophylla, E. forrestii* (KD), *E. platycalyx, Rhagodia eremaea, Thryptomene mucronulata.*
Low shrubs:	Dominant – *Ptilotus obovatus*, occasionally *E. forrestii* (KD). Common – *E. forrestii* (KD), *Maireana planifolia* (KD), *Ptilotus schwartzii* (KD), *Sida calyxhymenia* (KD), *Sida virgata, Solanum lasiophyllum.*
Perennial grasses:	Dominant – none. Common – *Monachather paradoxa*

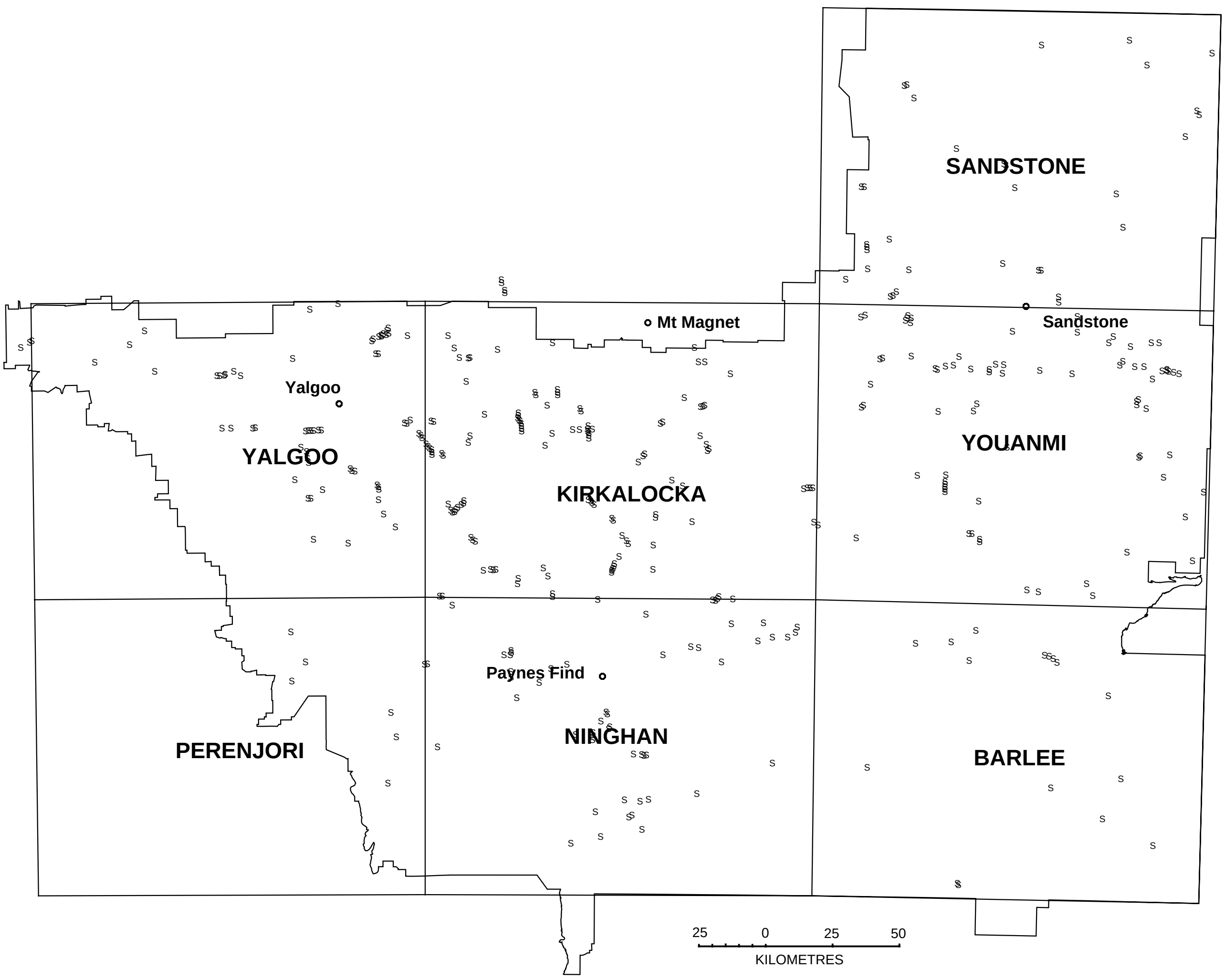

Figure 1. The distribution of traverse recordings of SGRS (S) habitat in the survey area

(facultative biennial), *Stipa elegantissima* (in south–west).

Other common plants: *Borya sphaerocephala* (resurrection plant), *Dianella revoluta* (lily).

Patterns of grazing impact

Natural variation in species composition appears to be much greater than that attributable to grazing impact.

More than half (59%) of the species recorded are not usually palatable to stock, however nearly three quarters of the individual shrubs counted at condition sites were palatable. It is then quite possible for overgrazing to substantially alter this habitat. Soils are typically very shallow, coarse-grained and stable.

A Detrended Correspondence Analysis (Hill 1979) ordination (Figure 2) of sites by log transformed individual species densities, revealed at best weak patterns in the species composition of sites likely to be due to grazing.

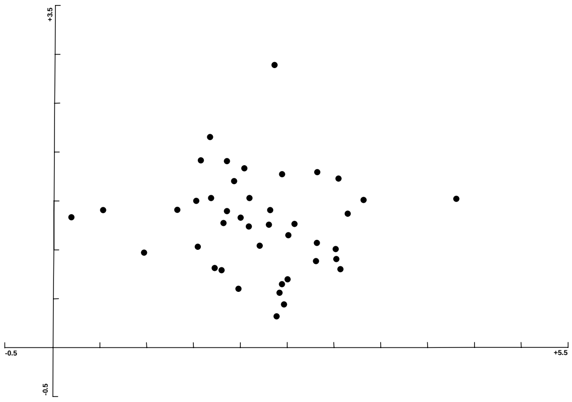

Figure 2. SGRS sites ordinated according to perennial species composition

Assuming the assignment of indicator values (based on accumulated experience of Agriculture Western Australia ecologists) was realistic; natural variation appears to be considerably more influential than grazing on botanical composition. Decreaser density is weakly correlated with ordination axis 1 ($R = 0.32$; $p = 0.02$), as was visual vegetation condition assessment ($R = 0.28$; $p = 0.04$).

The lack of obvious grazing influence on botanical composition of sites was further indicated by the absence of separate clustering of decreaser and increaser species in an ordination of the transformed sites x species matrix. *Senna artemisioides* subsp. *helmsii* (crinkle leaf cassia) and *Senna artemisioides* subsp. *sturtii* (variable cassia) were the commonest recorded increaser species, but occurred only four times each in 47 sites. The most common decreaser species included *Eremophila compacta*, *E. forrestii* (Wilcox bush), *E. latrobei* (warty leaf eremophila), *Maireana planifolia* (flat leaf bluebush), *Ptilotus obovatus* (cotton bush), *P. schwartzii* (horse mulla mulla), *Rhagodia eremaea* (tall saltbush) and *Sida calyxhymenia* (tall sida).

In an effort to identify some patterns of grazing impact, nine condition sites within 500m of the nearest watering point were compared with eight sites ranging from 4 to 7 km to the nearest watering point. Sites alternately this close to and far from the nearest water point might be expected to exhibit quite contrasting qualities including total cover, erosion and density of decreaser plants. They did not.

An interesting point emerged from the comparison of groups of sites at very different distances from water. Both groups were assessed, on average, to be closest to good range condition. The high level of natural variation in this habitat may be masking grazing impacts.

Nature conservation

The flora consists mostly of widely distributed species. *Verticordia interioris* (P3) was recorded at condition sites on two occasions. Although not well represented in nature reserves, it is not a preferred grazing habitat for stock and is very extensively distributed in the Eremaean Zone. It occurs in patches on Wanjarri Nature Reserve in the north–eastern Goldfields (Pringle 1993, 1994e, 1995b, Pringle *et al.* in prep).

Gradational associations

SGRS usually has clearly defined boundaries, except where patchy duricrusted residuals remain and it then forms a mosaic with *Breakaway mixed shrubland* (BRXS).

Land systems

Mainly Challenge, Olympic and Sherwood, less frequently and less extensively in most other granite–based land systems.

Other minor habitats in ‘stony plain and low rise sclerophyll shrubland habitats’

Granitic melaleuca acacia shrubland (GMAS) – 3 inventory sites

GMAS was sampled at three inventory sites in the far west of the survey area, although isolated examples occur as far east as Sandstone. It is very similar to *Sandy granitic acacia shrubland* (SGRS), but includes floristic components commonly associated with the South-West Botanical Province. Shrub cover is often moderately close (25–30% projected foliar cover), tall shrubs dominate and representative species such as *Calycopeplus ephedroides*, *Dodonaea inaequifolia*, *Grevillea pityophylla*, *Hibbertia glomerosa* and *Melaleuca uncinata*, are largely confined to the south and west. No priority species for conservation were identified, however this restricted but distinctive upland habitat was not sampled extensively.

C. STONY PLAIN AND LOW RISE CHENOPOD SHRUBLAND HABITATS

These are upland habitats that support chenopod shrubland. Chenopod is used in a generic sense to include all variously succulent low and mid shrubs associated with soils that are often base–rich and saline. Elsewhere this form of vegetation has been termed ‘succulent steppe’ (Beard 1981). The most common genera are *Atriplex* (saltbushes) and *Maireana*

(bluebushes) which are in the Chenopodiaceae, but also include families such as *Gunniopsis* (Aizoaceae) and *Frankenia* (Frankeniaceae).

These habitats are usually found in areas where erosional processes have only partially removed intensely weathered rock. Shallow soils derived locally from these residuals support these habitats, which usually contrast with adjacent generally sclerophyll tall shrubland with sub–ordinate, sparse understoreys. They usually have shallow, saline texture contrast (duplex) soils, which are susceptible to accelerated erosion where not protected by stone mantles.

Degradation of stony chenopod habitats observed during the survey has serious ramifications for both sustainable resource management and nature conservation. Stony chenopod habitats are generally preferentially grazed in favour of the two sclerophyllous habitats groups described previously. Compounding preferential grazing problems, almost all species are palatable and hence can be removed, leaving fragile soils exposed to erosion.

While most species are widely distributed, preferential grazing threatens this group of habitats. This group is poorly represented in nature reserves in the region (Pringle 1993, 1994a, 1995a). In several historically degraded areas that have been destocked for several years, the upland sclerophyll shrubland habitats appear to have regenerated considerably better than the stony chenopod areas, which showed little improvement. This may be due to soil degradation and consequent destruction of niches for the recruitment of perennial chenopods.

Maireana pyramidata *(sago bush) dominates this scattered low shrubland in SBMS habitat. This example is quite low in the landscape, as evidenced by a* Pittosporum phylliraeoides *(native willow) drainage focus in the background. Quartz stones are typical of this habitat and provide some protection against water erosion.*

11. Breakaway footslope chenopod low shrubland (BCLS)

Sampling 16 inventory and 21 condition sites

General information

This habitat was treated as part of other chenopod habitats in two adjacent regional surveys (Curry *et al.* 1994, Pringle *et al.* 1994). However, it is quite distinctive and has characteristics that require specific and sensitive land management.

BCLS occurs on the very gently inclined footslopes and alluvial plains deposited from the erosion of intensely weathered, generally granitic rocks underlying ferruginous duricrusts and exposed in breakaway scarps. Soils are usually shallow, saline duplexes over granite which may be subject to episodic saline seepage from the base of breakaway scarps (Churchward 1977). BCLS occurs throughout the survey area (Figure 3), but is replaced to some extent by BECW habitat described in the south of the survey area where a eucalypt overstorey is usually dominant.

Physiognomy and composition of vegetation

Vegetation generally consists of a very scattered to scattered (5–20% projected foliar cover) low shrubland usually without other recognisable strata. Seventy seven species were recorded at 16 inventory sites, at an average of 14 species per site, slightly below the survey average. BCLS shares its flora with many other chenopod habitats found in other positions in the landscape; it is distinctive in its physical environmental setting rather than in vegetation.

The following species (by strata) were dominant and/or common:

Trees:	None commonly dominant or frequent although *Eremophila longifolia* and *Eucalyptus loxophleba* were recorded.
Tall shrubs:	Occasional *Acacia* spp. recorded but rarely a recognisable stratum. Some of the scattered taller shrubs included *Acacia aneura, Eremophila oppositifolia* and *Hakea preissii* (KI).
Mid shrubs:	Dominant – nil. Common – *Atriplex bunburyana* (KD), *Senna artemisioides* subsp. *petiolaris, Dodonaea inaequifolia.*
Low shrubs:	Dominant – *Atriplex vesicaria* (KD), *Halosarcia* spp. and *Maireana glomerifolia* (KD). Common – *Atriplex bunburyana* (KD), *Senna artemisioides subsp. petiolaris, Enchylaena tomentosa* (KD), *M. platycarpa* (KD), *M. pyramidata* (KD), *M. tomentosa, M. trichoptera* (facultative biennial), *Ptilotus obovatus, Solanum lasiophyllum.*

Patterns of grazing impact

Sustained excessive grazing of this fragile habitat leads eventually to complete ecological collapse involving loss of perennial vegetation, increased surface soil salinity, widespread soil erosion and very little and extremely episodic biological activity. It is critical that land use is sensitive to the impacts of disturbance on this habitat.

Comparison of a range of sampling sites within conventional station paddocks with a smaller group of ‘reference’ sites negligibly or not affected by pastoral management revealed some clear differences. Characteristics

of sites in conventional paddocks (Table 2) include more soil erosion, reduced pastoral condition, reduced soil cryptogam (lichens, algae etc.) cover, reduced shrub cover, more (palatable) intermediate increaser species and lower shrub density than at reference sites. Less significant differences ($0.05 < p < 0.1$) include the presence of more unpalatable increaser species and lower decreaser shrub density at grazed sites. Clearly, these are aggregated differences in which numerous grazed sites resemble reference sites and more degraded sites do not. The ecological information in this analysis is important in identifying indicators of grazing impact. However, the low sampling frequency of 21 sites cannot be used to represent a regional assessment of the severity of modification by pastoralism.

It would appear that poor grazing management does not often trigger an increase of unpalatable shrubs, but where this happens it is likely that these shrubs invade rather than increase from a minor existing component of plant communities. This pattern was also found in chenopod communities fringing salt lake systems in the adjacent north-eastern Goldfields rangeland survey (Pringle 1994a).

The most commonly recorded decreaser species among the 21 sites include *Atriplex vesicaria*, *Frankenia* spp., *Maireana georgei* (George's bluebush), *M. glomerifolia* (ball-leaf bluebush), *Maireana platycarpa* (shy bluebush) and *M. pyramidata* (sago bush). *Hakea preissii* (needlebush) was the only increaser recorded at more than one site, occurring at four sites.

Such is the fragility of the soil and its susceptibility to localised secondary salinisation in BCLS, that niches for shrub recruitment are often destroyed in overgrazed situations.

BCLS is most common on breakaway footslopes of Sherwood and Gumbreak land systems. A third of these footslopes sampled during traverses were assessed as affected by soil erosion. Observations at both condition and inventory sites indicate that local areas receiving more concentrated tributary run-on are susceptible to rilling. More extensive interfluves and plains are often affected by sheet erosion through the upslope migration of micro-terraces. Patchy growth of forbs was closely linked to components of erosion cells migrating upslope. Stable surfaces immediately upslope of micro-terraces usually have a well formed cryptogamic crust (algae, lichens, liverworts and occasionally mosses) and support comparatively dense forbs. Exposed soil surfaces immediately downslope of micro-terraces are usually bare and have high surface salinities.

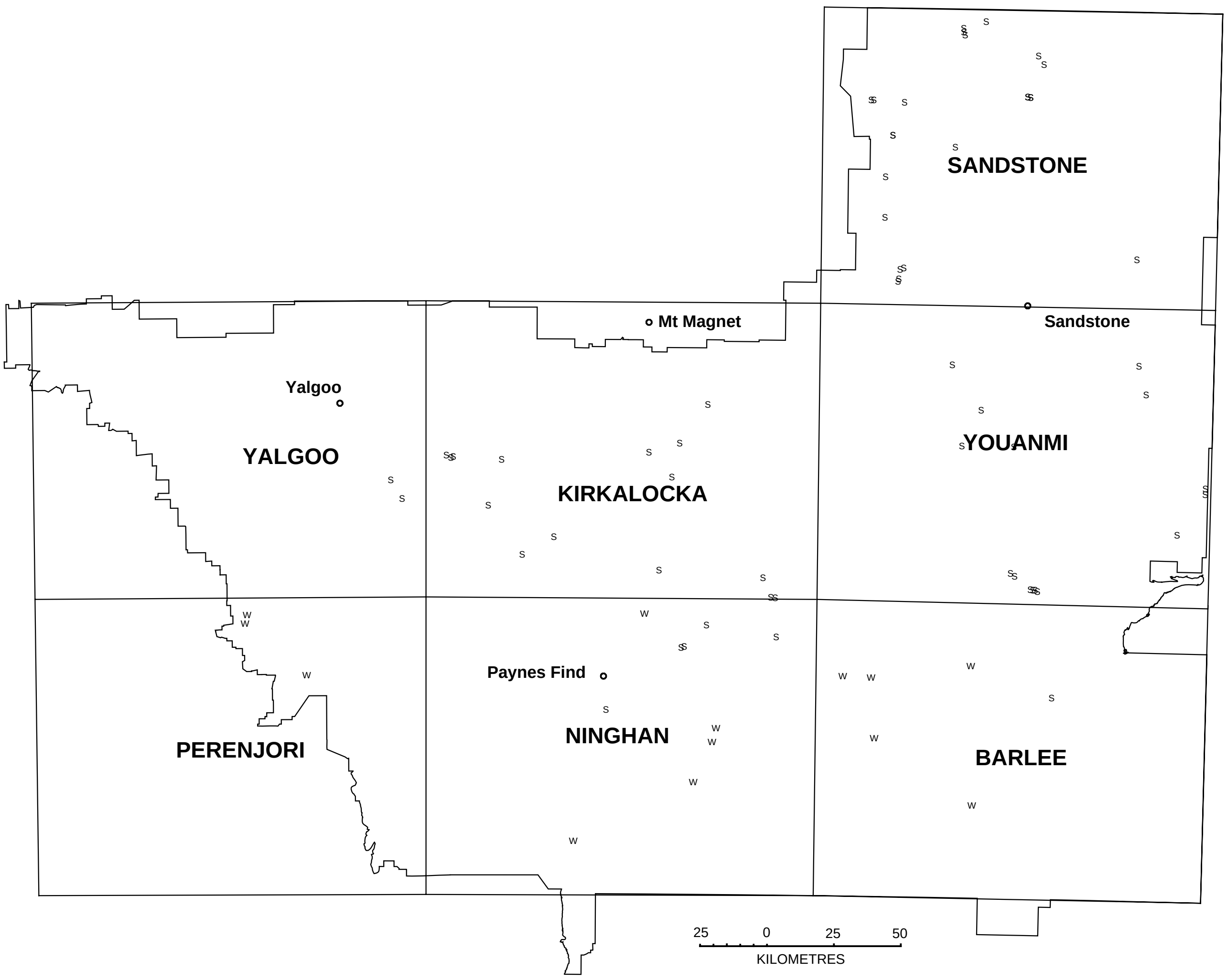

Figure 3. The distribution of traverse recordings of BCLS (S) and BECW (W) habitats in the survey area

Table 2.Comparison of attribute means for 14 conventionally grazed versus 7 reference sampling sites

Attribute	Grazed mean (and SE*)		Reference mean (and SE*)		T value	P <0.1
Erosion score	2.4	(0.2)	1.0	(0.0)	3.5	<0.01
Vegetation condition	2.9	(0.3)	1.0	(0.0)	4.0	<0.01
Surface crusting score	3.2	(0.5)	5.8	(0.9)	-2.8	<0.01
Projected foliar cover class	3.4	(0.2)	5.0	(0.4)	-4.4	<0.01
No. decreaser spp.	4.4	(0.5)	4.6	(0.5)	–	–
No. increaser spp.	0.4	(0.2)	0.0	(0.0)	1.3	0.08
No. intermediate spp.	1.2	(0.2)	0.4	(0.2)	2.6	0.01
Total number of species	8.1	(0.7)	7.7	(1.1)	0.4	–
Decreaser density (/ha)	934.6	(215.1)	1,551.4	(251.2)	-1.75	0.09
Increaser density (/ha)	62.9	(6.0)	0.0	(0.0)	–	–
Intermediate density (/ha)	38.8	(18.7)	6.4	(3.2)	–	–
Total density (/ha)	1,043.2	(205.7)	1,927.1	(294.5)	-2.5	0.02

* SE - Standard Error of the mean.

An absence of cryptogam, litter or shrub cover may lead to increased evaporation at the soil surface, leading to a rise of salts in soil solution by capillary action. Salts are concentrated at the soil surface, presumably preventing plant growth. As the micro-terracing progresses upslope, these previously exposed surfaces may be partially stabilised by the deposition of coarse materials eroded upslope which reduce capillary rise of salts and improve conditions for plant growth – until the next micro-terrace arrives from downslope.

In particularly degraded examples of this habitat, the coarse surface layer of soil has been almost completely stripped, occurring as isolated accumulations around obstacles. These accumulations may support ephemeral growth, but being unstable are unlikely to support many perennial shrubs. The soil surface between sandy accumulations is the sealed, saline, dispersive clay layer, which rarely supports any biological activity.

Soil erosion was significantly (p <0.01) greater at sites with a projected foliar cover less than 15%, which further indicates the importance of maintaining shrub cover for soil stability in this and other fragile habitats.

Nature conservation

Typical of the stony chenopod habitat group, BCLS rarely includes any rare or threatened species. However from a habitat or plant community perspective, it represents probably the most threatened pieces of land as a result of high preference placed on it by stock, the overwhelmingly palatable and accessible nature of its flora and the inherent fragility of its soils. Areas are represented on Wanjarri Nature Reserve in the adjacent north-eastern Goldfields (Pringle 1995b, Pringle *et al.* in prep) and several areas were sampled in this survey that appeared not to have been subject to normal pastoral grazing pressures.

Gradational associations

BCLS is usually quite different to adjacent habitats and has clearly defined boundaries. Occasionally chenopods extend some distance up the scree slopes of breakaway scarps.

Land systems

A common, but minor component in numerous land systems including Euchre, Gumbreak, Hootanui, Nerramyne, Sherwood, Waguin and Wiluna.

12. Breakaway footslope eucalypt woodland with chenopod understorey (BECW)

Sampling 4 inventory sites and data from an investigation on Mouroubra station south of Paynes Find.

General information

BECW shares the same physical environmental characteristics as BCLS described immediately above, but has a eucalypt overstorey in addition to a well developed chenopod low shrub stratum. It occurs in the south of the survey area, reflecting a transition into the South–Western Interzone and South–West Province of Beard (1991).

Physiognomy and composition of vegetation

The eucalypt overstorey is largely responsible for a slightly higher cover than in BCLS. BECW usually consists of a scattered to moderately close (15–25% projected foliar cover) low shrubland or woodland with a poorly developed mid shrub stratum and few tall shrubs or perennial grasses.

Forty-three species were recorded at the four inventory

sites, at an average of 17 species per site, slightly above the survey average of 16. The flora consists of species common to several other habitats.

The following species (by strata) are dominant and/or common:

Trees (or mallees):	Dominant – mainly *Eucalyptus loxophleba*, occasionally *E. salubris*. Common – no additional trees.
Tall shrubs:	Dominant – none; this stratum not clearly developed. Common – *Acacia acuminata* subsp. *burkittii, Eremophila oldfieldii, E. oppositifolia, Exocarpus aphyllus, Hakea arida*.
Mid shrubs:	Dominant – none. Common – *Dodonaea inaequifolia, Scaevola spinescens*.
Low shrubs:	Dominant – *Atriplex vesicaria* (KD), *Maireana georgei* (KD) and *Halosarcia* spp. Common – *Atriplex stipitata* (KI), *Enchylaena tomentosa* (KD), *Frankenia* spp., *Maireana trichoptera, M. villosa, Ptilotus obovatus, Rhagodia drummondii, Scaevola spinescens*.
Perennial grasses:	None recorded, however *Stipa elegantissima* was often present.

Patterns of grazing impact

Several of the more common low shrub species are removed under excessive grazing. These include *Atriplex vesicaria, Enchylaena tomentosa* and *Maireana georgei*. *Ptilotus obovatus* may then become more abundant, but can also be removed. *Atriplex stipitata* is not generally grazed and can succeed palatable species as the dominant understorey shrub. Its dominance may also be natural (Mitchell and Wilcox 1994).

Nature conservation

BECW is a preferred habitat for stock, feral animals (e.g. goats) and kangaroos. It is uncommon, occurring as isolated breakaway footslopes in the transitional area between pastoral and agricultural regions coinciding with the transition from the Eremaean to South–West Botanical Provinces.

Gradational associations

BECW usually occurs as a distinctive habitat with clear boundaries, but may grade downslope into *Plain York gum acacia woodland* (PYAW), as chenopods are replaced by taller sclerophyll species.

Land systems

Mainly Euchre and occasionally Graves.

13. Stony bluebush mixed shrubland (SBMS)

Sampling 23 inventory and 47 condition sites

General information

SBMS is common throughout the survey area (Figure 5), usually occurring on nearly level plains on weathered granite. It occurs less frequently and extensively in greenstone and basalt landscapes including the stony plains associated with Windimurra formation gabbros. It is least common in areas of extensive sandplain, where erosional surfaces are restricted, through much of the far south of the survey area.

Soils are generally shallow (<60 cm) texture contrast (duplex) types with stony mantles, mostly of quartz. SBMS occurs throughout the southern shrubland rangelands of Western Australia (Burnside *et al.* 1995).

Physiognomy and composition of vegetation

SBMS vegetation usually consists of a very scattered to scattered (2.5–15% projected foliar cover) low shrubland with considerably fewer prominent mid and tall shrubs. A total of 76 perennial species was recorded at 23 inventory sites, at an average of 12 species per site, somewhat lower than the survey average of 16 species. Most of these species are common to other habitats; only three species were also recorded in only one or two other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Rarely observed.
Tall shrubs:	Dominant – occasionally *Hakea preissii* (KI). Common – *Acacia aneura, A. acuminata subsp. burkittii, A. tetragonophylla, Hakea preissii* (KI).
Mid shrubs:	Dominant – none – this stratum was rarely recorded. Common – *A. tetragonophylla, Rhagodia eremaea, Scaevola spinescens*.
Low shrubs:	Dominant – most commonly *Maireana pyramidata* (KD). Common – *Senna artemisioides subsp. sturtii* (KI), *Frankenia spp., Maireana georgei* (KD), *M. glomerifolia* (KD), *M. triptera, Ptilotus obovatus, Rhagodia eremaea, Scaevola spinescens, Solanum lasiophyllum*.
Perennial grasses:	Rarely present and do not form a recognisable stratum.

Patterns of grazing impact

Excessive grazing beyond this habitat's capability leads to a decline in species such as *Maireana georgei*, accompanied by a general loss in shrub cover not equalled by increaser species such as *Hakea preissii.* The reduction in shrub cover leaves the soil susceptible to accelerated soil erosion, a process that reduces the possibility of successful regeneration.

Only one reference site was sampled which precludes analysis of aggregated grazing impacts in the context of reference status or variation. However, visual assessments based on perennial species composition and cover suggest that SBMS sites' vegetation was generally in fair to poor condition.

An ordination of log transformed species density values using Detrended Correspondence Analysis (Hill 1979) reveals strong patterning related to traditional understanding of range condition (Figure 5). Range condition scores for sites improve significantly towards the right of the plot ($R = -0.75$; $p < 0.001$), associated with an increase in shrub cover ($R = 0.44$; $p = 0.03$) and decreaser species density ($R = 0.75$; $p < 0.001$). Conversely, increaser density is higher towards the left of the ordination plot ($R = -0.56$; $p < 0.001$) and is associated with less extensive cryptogamic (lichens, algae etc.) crusting of the soil, an indicator of soil health and stability (Tongway 1994). The ordination of sites indicates, at least according to these two axes, that the variation is relatively continuous. Sites with fewer than 10 shrubs per 1,000m^2 have been removed. They may represent a separate ecological state (Westoby *et al.* 1989), whereby the system has crashed and a return to a perennial shrubland may be difficult to achieve in human time.

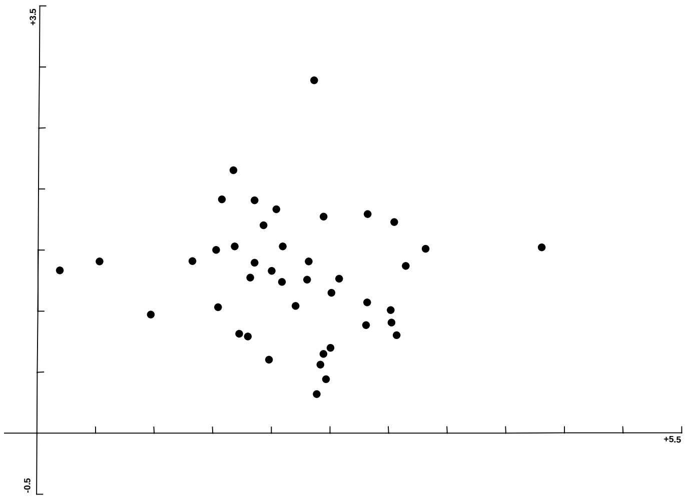

Figure 5. Ordination of SBMS sites according to perennial species composition

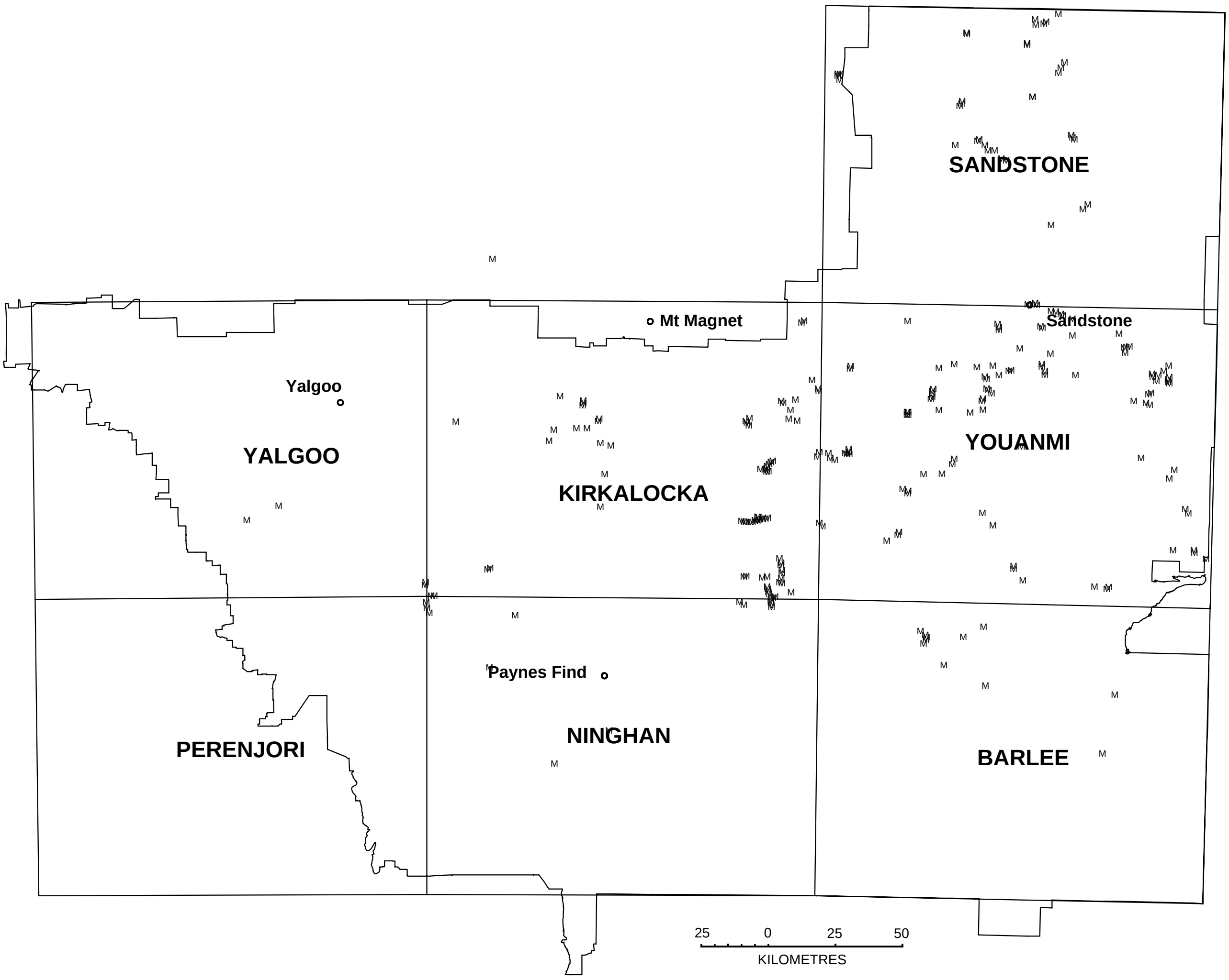

Figure 4. The distribution of traverse recordings of SBMS (M) habitat in the survey area

When shrub cover declines below 10%, erosion appears to become more frequent and more extensive within sites. The increaser species clearly do not compensate for lost palatable shrub cover and hence overgrazing predisposes SBMS to accelerated soil erosion.

The common recorded decreaser species include *Frankenia* spp., *Maireana georgei* (George's bluebush), *M. glomerifolia* (ball-leaf bluebush), *M. pyramidata* (sago bush) and *Rhagodia eremaea* (tall saltbush). The more common increaser species include *Eremophila lachnocalyx* and *Hakea preissii* (needlebush).

Nature conservation

While of little specific conservation value in terms of plant species, the fact that SBMS is preferentially grazed and has fragile soils, particularly where soil mantles are not substantial, makes it a threatened habitat under extensive pastoral land use. Degraded areas appear not to regenerate readily, possibly as a result of soil degradation.

Gradational associations

SBMS grades into *Upland small bluebush species shrubland* (USBS) as soils become shallower and stonier and downslope into *Plain sago bush shrubland* (PSAS) as alluvial processes become more influential, quartz mantles sparser and soils deeper.

Land systems

Most extensive in Challenge, Gransal, Hootanui, Nallex, Nubev, Sherwood and Wiluna, less in Merbla, Naluthanna and Sherwood.

14. Upland small bluebush species shrubland (USBS)

Sampling 4 inventory sites

General information

USBS supports a blend of chenopod and sclerophyll vegetation on the shallowest, poorest soils of the stony chenopod habitats. Soils are generally very shallow (<30 cm) red earths or duplexes with dense stony mantles. USBS was first described in the north-eastern Goldfields (Pringle 1994a) and is most common (though never extensive) in the north–east of the survey area.

Physiognomy and composition of vegetation

Generally very scattered (2.5–10% projected foliar cover) tall or low shrubland, with few if any trees and perennial grasses. Forty-five perennial species were recorded at the four USBS inventory sites, at an average of 18 species per site, somewhat higher than the survey average of 16. This possibly reflects the representation of both chenopod and sclerophyll habitat species, as this is a relatively harsh habitat. No species recorded were particularly distinctive.

The following species (by strata) are dominant and/or common:

Trees:	No strata recognised and none common.
Tall shrubs:	Dominant – *Acacia aneura*, *Hakea preissii*. Common – *A. ramulosa, A. tetragonophylla, Eremophila oldfieldii, E. platycalyx.*
Mid shrubs:	Dominant – *Acacia tetragonophylla.* Common – *A. ramulosa, Senna artemisioides* subsp. *petiolaris, Eremophila latrobei* (KD), *Hakea preissii* (KI), *Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – variable; *Eremophila lachnocalyx, M. georgei, M. triptera* or *Ptilotus obovatus.* Common – *Senna artemisioides* subsp. *petiolaris, Enchylaena tomentosa* (KD), *Eremophila latrobei* (KD), *Rhagodia eremaea, Scaevola spinescens, Sida calyxhymenia* (KD), *Solanum lasiophyllum.*
Perennial grasses:	Rarely observed.

Patterns of grazing impact

Sustained heavy grazing pressure is likely to result in the decline of some species, including *Enchylaena tomentosa, Maireana georgei* and *Eremophila latrobei*, perhaps with increases in *Hakea preissii* and *Maireana triptera*. The abundance of *M. triptera* closely reflects the nature of recent seasons. Relatively intact USBS should support a variable mix of palatable chenopod and sclerophyllous low shrubs. Soils are generally stable, protected by heavy stony mantles.

Nature conservation

This minor habitat appears to have little specific conservation value.

Gradational associations

USBS grades into *Stony bluebush mixed shrublands* (SBMS) as soils become deeper.

Land systems

A minor component of Gransal, Nubev, Sherwood and Wiluna.

Other minor habitats in the 'stony plain and low rise chenopod shrubland habitats'

Stony saltbush mixed shrubland (SSMS) – 3 inventory sites

SSMS was sampled at three inventory sites. It is rare and it is not known whether it may once have been more widespread, but has been altered to more resilient bluebush

(*Maireana* spp.) vegetation in some areas (e.g. SBMS). SSMS sites were scattered (10-15% projected foliar cover) low shrubland dominated by *Atriplex vesicaria* and occurred in greenstone-dominated landscapes. It is difficult to discuss conservation value without knowing whether current examples are relics of a more extensively distributed but altered habitat. If the former is so, it has high conservation value as a threatened habitat under extensive pastoral land use.

D. ALLUVIAL PLAIN WITH CONSPICUOUS CHENOPOD SHRUBLAND HABITATS

This group of habitats occurs in depositional landscapes and is characterised by an often dominant low shrub stratum of succulent or semi-succulent ('chenopod') shrubs, referred to as 'succulent steppe' by Beard (1991). Habitats of this type extend from the Pilbara e.g. the 'Marsh' of the Fortescue River on Roy Hill station (Payne and Mitchell 1993) through to the Nullarbor Plain (Mitchell *et al.* 1979).

Chenopod plains are most commonly associated with texture contrast (duplex) soils, but also occur on clay soils (as described below). Soil stability varies according to the intensity of run-on that areas receive. The alluvial plains adjacent to salt lakes are almost level and subject to relatively low energy surface flows and usually quite stable (Pringle 1994c), while plains receiving distributary flow from ephemeral creeks and rivers receive more energetic flow and more frequently have their subsoil exposed in degraded areas. Preferential grazing of the latter exacerbates the problem and few extensive areas of this type of habitat remain intact (e.g. Pringle 1994d, Payne and Pringle this report).

This group has the highest pastoral value in the arid southern shrubland rangelands and has been the subject of much rangeland research on grazing ecology. Hacker (1979) studied chenopod plains on Glenorn station in the north-eastern Goldfields east of this survey area. He recognised that excessive grazing pressure reduces shrub cover, which in turn can lead to the extension of naturally present small scalds in a manner not reversible by the easing of grazing pressures alone. Hacker emphasises the need for land management to avoid this form of degradation by maintaining shrub cover well above critical thresholds.

Hacker's observations contrast with those of Holm *et al.* (1994), who undertook a 10-year study on chenopod plains associated with the Gascoyne River on Boolathana station. They found that soils were generally stable in areas where shrub cover had been substantially reduced. This research was conducted on the Sable land system (Payne *et al.* 1988), which has low energy run-on, while Hacker's studies were on more concentrated tributary plains upslope of salt lakes.

Wind erosion can be severe in extended dry periods if shrub cover is lost. Sand drifts frequently covered the Leonora-Kalgoorlie road across the Jeedamya flats in the early 1970s. This area has regenerated into very healthy chenopod shrubland with stabilised soils under conservative pastoral management, indicating the resilient nature of alluvial plains surrounding salt lakes (Pringle 1994a).

At a regional scale, major south-westward flowing drainage systems such as the Warne River are susceptible to severe degradation, while the salt lake systems such as Lake Barlee and Lake Moore are considerably more inherently stable.

Hacker (1979) also found that soil surface characteristics such as salinity varied considerably within habitats, favouring the recruitment of different species and creating an internal patchwork of grazing preferences by stock. Watson and Holm (1990) found that light grazing (conservative stocking rates) improved the resilience to drought of some perennial species, observing considerably higher drought mortality in exclosed areas. This suggests that under conservative pastoral management, the maintenance of perennial floristic diversity may be achieved, a situation proposed elsewhere (Curry and Hacker 1990, West 1993, Morton and Stafford Smith 1994).

While most of these habitats do not have a substantial overstorey, *Acacia eremaea* (snakewood) and *A. masliniana* (spiny snakewood) occur on duplex soils and *Eucalyptus loxophleba*, *E. salmonophloia* and *E. salubris* extend northwards into the survey area, often on clay soils. Perennial grasses such as *Eriachne flaccida* and *Eragrostis setifolia* are common amongst chenopods on cracking clay soils, particularly those associated with alluvium derived from Windimurra complex gabbros.

Extensive chenopod shrublands dominate habitats in the lowest, most fertile parts of the landscape. In this example (SSAS habitat) Atriplex bunburyana *(silver saltbush) and* Cratystylis subspinescens *(sage) are the dominant shrub species. These depositional habitats benefit from run-on received from higher in their catchments. Surface soils are often sandy, which facilitates infiltration and deeper soil layers are often light clays which can retain infiltrated water. Healthy soil surfaces have a well developed cryptogam crust.*

15. Alluvial plain snakewood chenopod shrubland (ASWS)

Sampling 26 inventory sites

General information

ASWS occurs on plains throughout the survey area, but most frequently in the north-west adjacent to the Murchison River catchment survey (Curry *et al.* 1994). It occurs both on alluvial plains and sandy banks in depositional landscapes, with duplex or sandy textured soils respectively. It differs in this respect from many snakewood communities further north in the Murchison River catchment, which tend to occur on the transitional interfluves between erosional and depositional landscapes (Curry *et al.* 1994).

Physiognomy and composition of vegetation

ASWS generally consists of scattered to moderately close (10-25% projected foliar cover) shrubland dominated most frequently by tall shrubs, but not uncommonly by low shrubs.

It appears that the development of the understorey is inversely related to that of the upperstorey. In well developed tall shrubland there is often clumping of low shrubs under larger acacias.

One hundred and ten perennial species were recorded at the 26 inventory sites at an average of 18 per site, a little over the survey average of 16. While dominance by *A. eremaea* (snakewood) and *A. masliniana* (spiny snakewood) is characteristic of ASWS, no species are confined to it.

The following species (by strata) are dominant and/or common:

Trees:	Not common.
Tall shrubs:	Dominant – *Acacia eremaea* and *A. masliniana.* Common – *A. acuminata* subsp. *burkittii, A. tetragonophylla, Exocarpos aphyllus* and *Santalum spicatum.*
Mid shrubs:	Dominant – frequently recorded, but floristically very variable. Common – *A. masliniana, A. tetragonophylla*, *Senna glutinosa* subsp. *charlesiana*, *Cratystylis subspinescens, Eremophila scoparia, Ptilotus divaricatus*, *Rhagodia eremaea* and *Scaevola spinescens.*
Low shrubs:	Dominant – always well developed but very variable floristically. Common – *Atriplex bunburyana* (KD), *Cratystylis subspinescens, Enchylaena tomentosa* (KD), *Frankenia spp.*, *Maireana georgei* (KD), *M. pyramidata, M. triptera*, *Ptilotus obovatus*, *Rhagodia drummondii, R. eremaea, Scaevola spinescens* and *Solanum lasiophyllum.*
Perennial grasses:	Dominant – rarely recorded as a stratum. Common – *Stipa elegantissima.*

Patterns of grazing impact

The tall shrub stratum appears not to be affected by grazing, although it is not known whether grazing can suppress recruitment of new acacias. The impact of excessive grazing pressures is likely to include reduction in the abundance and eventual removal of palatable understorey species including *Atriplex bunburyana, A. vesicaria, Enchylaena tomentosa* and *Maireana georgei*. This may first occur in the open and then progressively into tall shrub canopy understoreys. Under such circumstances, these species are also unlikely to recruit replacements. Invasive species such as *Hakea preissii* may also become established in degraded areas (Curry *et al.* 1994).

Nature conservation

ASWS is a preferentially grazed habitat susceptible to reduction in palatable low shrub species cover and richness. *Acacia kalgoorliensis* (P3) was recorded at one inventory site.

Gradational associations

ASWS is usually a clearly defined habitat with a distinctive acacia upperstorey setting it apart from adjacent chenopod communities.

Land systems

Carnegie, Challenge, Ero, Mileura, Joy, Mileura, Tindalarra and Yewin.

16. Bladder saltbush low shrubland (BLSS)

Sampling 5 inventory sites

General information

BLSS is characterised in its intact state by the dominance of *Atriplex vesicaria*. It was first described in its own right in the adjacent north-eastern Goldfields survey (Pringle 1994a) and as a component of *Saltbush Shrubland* vegetation type in the Murchison River catchment survey (Curry *et al.* 1994).

It generally occurs on texture contrast soils on alluvial plains in salt lake country and tributary alluvial systems in zonations and mosaics with samphire and *Frankenia* spp.

BLSS is susceptible to weevil attacks following good seasonal conditions. This is probably a part of natural dynamics and it is unlikely that anything practical and cost effective can be done to retard attacks on *A. vesicaria*. In pastoral paddocks, easing grazing pressure may help stressed plants to survive and maintain the foliar cover of unaffected plants to prevent degradation of the soil surface.

BLSS habitat refers specifically to *A. vesicaria*-dominated alluvial plains in depositional landscapes. Breakaway footslopes dominated by this plant are treated as a separate habitat (BCLS – previously discussed), as would *A. vesicaria* plains on the Nullarbor Plain. Their landscape settings and associated processes are quite different even if they appear quite similar botanically.

Physiognomy and composition of vegetation

BLSS usually occurs as scattered to moderately close (10-25% projected foliar cover) low shrubland with occasional taller shrubs, which rarely form a distinct stratum.

Forty species were recorded at the five inventory sites, at an average of 11 species per site, noticeably lower than the survey average of 16. Sites in the adjacent north-eastern Goldfields survey averaged 8.2 species per site (Pringle 1994a), which supports the proposal that BLSS is a habitat with specific physical environmental characteristics not suitable to many of the chenopod species. Soil salinity may be a major factor. Other habitats found at the lowest, saline part of the landscape are similarly species poor (e.g. samphire flats – SAMP). Those species recorded in BLSS are common

in other habitats.

The following species were dominant and/or common in the low shrub stratum:

Low shrubs: Dominant – *Atriplex vesicaria* (KD). Common – *Cratystylis subspinescens, Frankenia spp., Gunniopsis quadrifida, Maireana atkinsiana* (KD), *M. pyramidata, M. tomentosa* and *Scaevola spinescens*.

Taller shrubs commonly encountered in small numbers include *Acacia tetragonophylla, Eremophila miniata* and *Hakea preissii* (KI).

Patterns of grazing impact

Sustained excessive grazing pressures are likely to reduce the cover and number of sensitive species such as *Atriplex vesicaria* and *Maireana atkinsiana*. Some degraded areas observed while traversing through lake country appeared to have high proportions of *Eremophila malacoides, Hakea preissii* and *Maireana triptera*. Healthy BLSS soils have well developed cryptogamic crusts of algae, lichens and liverworts, which provide some protection against soil surface disturbance and may provide a mulching effect, retarding the rise of salt through capillary flow driven by evaporation at the soil surface. Soil surface disturbance may lead to the spread of small saline patches.

Nature conservation

BLSS is a preferentially grazed habitat in areas with water suitable for stock. It is a moderately threatened habitat in such pastoral areas. It occurs in the lake country fringing Lake Barlee on Mt Elvire station, a pastoral lease purchased by the CALM in May 1991.

Gradational associations

BLSS often occurs in mosaics with other habitats and grades upslope into *Maireana* dominated habitats. There may well be some grazing related succession of *Atriplex* by *Maireana* species (particularly *M. pyramidata* and *M. triptera*) expressed as zonational shifts in their boundaries.

Land systems

Mainly Carnegie, some tributary systems such as Campsite.

17. Gilgai grassy low shrubland (GGLS)

Sampling 4 inventory sites

General information

GGLS is a distinctive chenopod shrubland/tussock grassland mosaic and occurs on cracking clay soils on alluvial plains developed from medium to coarse grained mafic basalts – the Windimurra gabbros. It is most common on Windimurra station on Merbla land system. There are two mosaic expressions of GGLS. The tussock grass component dominates the gilgai soil phase in the alluvial plains which either occur in sinuous patterns on central drainage floors, or in near parallel bands perpendicular to the direction of sheet flow (i.e. along the natural contour of the land). The grass phase is very fragmented on interfluves, but may continue considerable distances downslope in central drainage tracts. Chenopod shrubs dominate the inter gilgai areas on interfluves and flank central drainage tracts. There is some overlap in the floras of these two phases.

The soils are deep (>60 cm) red clays or cracking clays and exhibit a degree of structural development unusual in this region. The inherent fertility is clearly illustrated by the thickets of *Carthamus lanatus* (saffron thistle) that can exceed 3 m in height. Biomass production of herbaceous growth in good seasons is extraordinarily high. GGLS extends northwards into the south-eastern corner of the Murchison River catchment survey, where it was included in *Alluvial Tussock Grassland* vegetation type (Curry *et al.* 1994), which included a small number of other habitats not found in this survey area.

Physiognomy and composition of vegetation

GGLS generally consists of a scattered (10-20% projected foliar cover) low shrubland with patches of tussock grasses that rarely exceed 5% basal area.

Twenty perennial species were recorded at the four inventory sites, at an average of 9 per site, well below the survey average of 16.

The following species are dominant and/or common in the low shrub and tussock grass layers:

Low shrubs: Dominant – *Maireana pyramidata*. Common – *Atriplex bunburyana* (KD), *Enchylaena tomentosa* (KD), *Maireana triptera, Ptilotus obovatus, Rhagodia eremaea, Solanum lasiophyllum*.

Perennial grasses: Dominant – *Eriachne flaccida*. Common – *Eragrostis setifolia*.

Also common in low numbers are *Acacia tetragonophylla* and *Pittosporum phylliraeoides*.

Patterns of grazing impact

Little is known about grazing impacts; the following discussion generalises from previous findings in other chenopod habitats (e.g. Curry *et al.* 1994; Pringle, 1994a; Hacker, 1979) and alluvial tussock grasslands (Payne *et al.* 1988).

It is possible that *Atriplex bunburyana* was once more abundant at the sites sampled and has been partly replaced by species such as *Maireana pyramidata* and *Ptilotus obovatus.* Certainly, one might expect *A. bunburyana* and *Enchylaena tomentosa* to decline under sustained excessive grazing pressure. Similarly, one might expect the nutritious *Eragrostis setifolia* to decline. Many areas in which exotics such as saffron thistle have proliferated appeared (on the basis of few perennial shrubs) to have been degraded, begging the inference that intact GGLS is considerably less susceptible to invasion by exotics.

Nature conservation

GGLS may prove to have high conservation value for a number of reasons. First, it is an extraordinarily fertile habitat for the eco-region and presumably has the capacity to act both as a drought refuge and a breeding habitat for various levels of fauna (see Morton *et al.* 1995, Morton and Stafford Smith 1994). Second, it is a rare example, for this eco-region, of an alluvial habitat that supports tussock grasses, some of which are susceptible to removal by preferential grazing. Third, it is a habitat that is extraordinarily susceptible to invasion by exotic species, probably as a result of its inherent fertility and preference as a grazing habitat. It is therefore both a restricted and threatened habitat.

Gradational associations

GGLS is fairly distinctive, but may grade into other chenopod habitats without cracking clay soils. *Eriachne flaccida*, commonly the dominant grass, is distinctive and appears not to be particularly attractive to stock.

Land systems

Mainly Merbla, restricted tracts in Nallex and Nalluthanna.

18. Plain eucalypt chenopod woodland (PECW)

Sampling 21 inventory sites

General information

PECW was first described in the adjacent north-eastern Goldfields survey area (Pringle 1994a) as two sub-types; one with a *Maireana sedifolia* or *M. pyramidata* (bluebushes) understorey and blackbutt trees (e.g. *Eucalyptus lesouefii*) on calcareous stony plains and erosional slopes (PEBW type) and *Atriplex vesicaria* understorey with *E. salmonophloia* and *E. salubris* trees (PESW) on alluvial plains. PESW is the common type in this survey area.

It is found is the southern half of the survey area, particularly in the far south-east and extending westwards onto the Ninghan 1:250,000 scale map sheet. Soils are generally calcareous loams grading downslope to clay loams or clays on alluvial plains.

Physiognomy and composition of vegetation

PECW generally consists of a scattered to moderately close (10-25% projected foliar cover) woodland with a well developed, occasionally dominant or co-dominant, low shrub stratum. One hundred and nine perennial species were recorded at the 21 inventory sites at an average of 17 species per site, marginally higher than the survey average.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – variable eucalypts; most commonly *Eucalyptus salubris*, occasionally *E. loxophleba* or *E. salmonophloia*. Common – *E. salubris* with other eucalypts.
Tall shrubs:	Dominant – variable; *Eremophila scoparia* most commonly. Common – *Acacia acuminata* subsp. *burkittii*, *E. scoparia*, *Exocarpos aphyllus*.
Mid shrubs:	Dominant – variable; *E. scoparia* most common. Common – *Atriplex nummularia* (far south-east), *Senna artemisioides* subsp. *filifolia* (KI).
Low shrubs:	Dominant – variable; *Atriplex vesicaria* (KD) most common. Common – *Atriplex stipitata*, *A. vesicaria* (KD), *Senna artemisioides* subsp. *filifolia* (KI), *Enchylaena tomentosa*, *Maireana georgei* (KD), *M. triptera*, *Olearia muelleri*, *Ptilotus obovatus*, *Rhagodia drummondii*.
Perennial grasses:	Dominant – none; stratum rarely present. Common – *Stipa elegantissima*.

Patterns of grazing impact

The understorey usually contains a mix of species, most of which are attractive forage for stock and can be removed under sustained heavy grazing pressures. These include *Atriplex bunburyana*, *A. vesicaria*, *Enchylaena tomentosa* and *Maireana georgei*. *Atriplex stipitata* looks very similar to *A. vesicaria*, but has a bitter taste so is therefore not attractive to stock and may succeed more palatable species in degraded areas. It also dominates some ungrazed areas, hence its dominance is not conclusive proof of a grazing induced succession. Other species that may succeed more palatable species include *Acacia hemiteles*, *Senna artemisioides* subsp. *filifolia* and *Dodonaea lobulata*. Where low shrub cover has been substantially reduced *Sclerolaena* species may proliferate in good seasons. Dense stands of *Eremophila scoparia*, palatable to stock and more particularly to feral goats, may indicate past overgrazing or disturbance (e.g. fire or severe hail storms). Soils are generally stable.

Nature conservation

PECW is a minor component of this area, but considerably more extensive south-east towards and beyond Coolgardie and Kalgoorlie.

Gradational associations

The gradual changes in vegetation with relief so characteristic of PECW in the north-eastern Goldfields and further south, are not often or well developed in this survey area. PECW is a distinctive and usually clearly defined habitat.

Land systems

Most common in Moriarty and Campsite; also in Doney, Euchre, Gumbreak, Hootanui and Mulline.

19. Plain York gum chenopod woodland (PYCW)

Sampling 16 inventory sites

General information

PYCW is named after *Eucalyptus loxophleba* (York gum), a species recognised by Beard (1991) as a regional dominant along the middle of the northern boundary of the South-West Botanical Province. Unlike PECW described immediately above, PYCW occurs most commonly in alluvial systems in granite-dominated landscapes and has loamy duplex soils rather than clays. It also extends from the south-east of the survey farther west into the Perenjori and Yalgoo map sheets, having more affinity with the wheatbelt than the Goldfields.

Physiognomy and composition of vegetation

PYCW usually occurs as scattered (10-20% projected foliar cover) woodlands with a prominent (sometimes dominant) low shrub stratum and less conspicuous mid and tall shrubs (but more so than in PECW).

One hundred perennial species were recorded at the 16 inventory sites at an average of 18 species per site, a little higher than the survey average of 16.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Eucalyptus loxophleba*. Common – no others common.
Tall shrubs:	Dominant – very variable. Common – *Acacia acuminata* subsp. *burkittii*, *A. ramulosa*, *A. tetragonophylla*, *Exocarpos aphyllus*.
Mid shrubs:	Dominant – very variable. Common – *A. tetragonophylla*, *Senna artemisioides* subsp. *filifolia* (KI), *Rhagodia eremaea.*
Low shrubs:	Dominant – very variable, often Atriplex spp. Common – *Atriplex bunburyana* (KD), *A. stipitata*, *Senna artemisioides* subsp. *filifolia* (KI), *Enchylaena tomentosa* (KD), *Maireana georgei* (KD), *M. triptera*, *Ptilotus obovatus*, *Rhagodia drummondii*, *R. eremaea.*
Perennial grasses:	Dominant – occasionally *Stipa elegantissima.* Common – *S. elegantissima.*

Patterns of grazing impact

While no condition site sampling was undertaken for this habitat, grazing impacts were observed during daily traverses. These involved succession of palatable understorey species e.g. *Atriplex vesicaria* and *Maireana georgei* by unpalatable species. *Senna artemisioides* subsp. *filifolia* is a common replacement for more palatable and nutritious shrubs. Soil erosion can become a problem in areas receiving run-on, particularly where shrub cover has been substantially reduced.

Nature conservation

PYCW is a preferentially grazed habitat in a region with extensive, less preferred sclerophyll shrubland on coarser textured soils. It is also cleared in the adjacent agricultural area to the south for crops. For these reasons, rather than botanical composition, it probably has comparatively high regional conservation value.

Gradational associations

On coarser textured soils the chenopod low shrub layer grades to denser, taller sclerophyll shrubs with York gum (*Plain York gum acacia woodland* – PYAW), in which it may occur in small patches associated with local drainage features.

Land systems

Most common and extensive in Doney and Euchre, less in Pindar and Carnegie.

20. Plain sago bush shrubland (PSAS)

Sampling 31 inventory sites

General information

PSAS was first described in its own right in the adjacent north-eastern Goldfields survey (Pringle 1994a) and was a major part of *Bluebush Shrubland* vegetation type in the Murchison River catchment survey (Curry *et al.* 1994).

Named after its commonly dominant species, *Maireana pyramidata* (sago bush), it occurs on nearly level alluvial plains with texture contrast (duplex) soils on hardpan, most extensive in the upper sectors of alluvial plains draining down into salt lakes and tributary systems carrying diffuse sheet flow. A natural habitat in its own right, it may be mistaken for *Atriplex bunburyana* (SSAS) habitats in concentrated drainage systems where *M. pyramidata* has succeeded *A. bunburyana* due to past heavy grazing pressures.

PSAS occurs throughout the survey area, but is considerably more common in the Eremaean north-east.

Physiognomy and composition of vegetation

PSAS usually occurs as very scattered to scattered (5-15% projected foliar cover) low shrubland, occasionally with a poorly developed mid or tall shrub stratum.

Eighty-nine perennial species were recorded at the 31 inventory sites at an average of 11 species per site, somewhat below the survey average of 16 species. Almost all species found in PSAS are common to other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Rarely present.
Tall shrubs:	Dominant – only a third of sites had this stratum; no common dominant. Common – *Acacia aneura*, *A. tetragonophylla*, *Hakea preissii* (KI).
Mid shrubs:	Dominant – less than a third of sites had

	this stratum; no common dominant. Common – *Hakea preissii* (KI), *Rhagodia eremaea.*
Low shrubs:	Dominant – *Maireana pyramidata.* Common – *Frankenia* spp., *Halosarcia* spp., *Maireana georgei* (KD), *M. triptera, Ptilotus obovatus, Rhagodia eremaea, Solanum lasiophyllum.*
Perennial grasses:	Rarely present and never as a recognisable stratum.

Patterns of grazing impact

Maireana pyramidata is notably resistant to grazing (Mitchell and Wilcox 1994) and hence impacts are more readily seen in the mix and abundance of smaller perennial shrubs. The mix of species most likely to decline as a response to heavy grazing includes *Atriplex* spp., *Enchylaena tomentosa* and *Maireana georgei*, perhaps to be replaced by *M. triptera, Ptilotus obovatus* and *Solanum lasiophyllum*, particularly in runs of good seasons. An increase in *Hakea preissii* is a reliable indicator of previous overgrazing, although this species rarely forms the 'woody weed' thickets of river systems to the north (e.g. Payne *et al.* 1988).

Soils are generally not susceptible to substantially accelerated erosion, however the breakdown of sandy bush mounds represents the loss of major recruitment niches. Soil stability is partly due to lack of slope and the diffuse nature of surface run-on and is assisted by cryptogamic crusting.

Nature conservation

Observations at fence-line effects reveal that PSAS is a preferentially grazed habitat and has relatively stable soils. It contains flora common to many other habitats.

Gradational associations

Observations at fence-line effects reveal that PSAS may expand laterally into more concentrated drainage systems naturally supporting *Atriplex bunburyana* dominated plant communities, or downslope into a variety of habitats dominated often by *Atriplex vesicaria* or smaller *Maireana* species including *M. atkinsiana* and *M. platycarpa*. This expansion is usually driven by grazing disturbance. PSAS also naturally grades into these habitats.

Land systems

Mainly Carnegie, Ero, Gransal, Gumbreak, Hootanui, Merbla, Mileura, Nallex, Sherwood and Wiluna.

21. Plain mixed halophyte shrubland (PXHS)

Sampling 15 inventory sites

General information

PXHS has previously been described in some detail in both the Murchison River catchment (MXHS – Curry *et al.* 1994) and north-eastern Goldfields surveys (Pringle 1994a). In both cases, grazing ecology was investigated in some detail. PXHS characterises many of the alluvial plains with saline texture contract (duplex) soils, often over hardpan adjacent to salt lakes. It usually consists of a mosaic of sub-communities, all with different dominant species, as opposed to similar chenopod habitats such as that discussed immediately above (PSAS). These differences probably reflect subtle patterns relating to soil hydrology and salinity (Hacker 1979).

PXHS occurs through most of the survey area. *Atriplex bunburyana* (SSAS) and *Maireana pyramidata* (PSAS) tend to dominate the major creek and river systems such as the Greenough and Warne Rivers.

Physiognomy and composition of vegetation

PXHS usually occurs as a very scattered to scattered (5-15% projected foliar cover) low shrubland, often without any other conspicuous strata. Sixty-nine perennial species were recorded at the 15 inventory sites, at an average of 13 species per site, somewhat lower than the survey average of 16. PXHS species are common to other habitats.

The following species (by strata) were dominant and/or common:

Trees:	Rare.
Tall shrubs:	Dominant – stratum rarely present. Common – *Acacia tetragonophylla* and *Hakea preissii* (KI).
Mid shrubs:	Dominant – recorded at less than a third of sites; no common species.
	Common – *Atriplex bunburyana* (KD), *Cratystylis subspinescens* (KD), *Ptilotus divaricatus.*
Low shrubs:	Dominant – very variable; 8 dominant species at 15 sites.
	Common – *Atriplex amnicola* (KD), *A. bunburyana* (KD), *A. vesicaria* (KD), *Cratystylis subspinescens* (KD), *Enchylaena tomentosa* (KD), *Eremophila maculata, Frankenia* spp., *Halosarcia* spp., *Maireana georgei* (KD), *M. glomerifolia* (KD), *M. pyramidata, M. triptera, Ptilotus obovatus, Scaevola spinescens.*
Perennial grasses:	Rarely present.

Patterns of grazing impact

Curry *et al.* (1994) suggested that excessive grazing reduces projected foliar cover and that when a threshold is crossed (7.5% was proposed) PXHS becomes susceptible to combinations of accelerated soil erosion and/or increases in unpalatable shrubs with invasive tendencies. Pringle (1994a) compared 15 ungrazed 'reference' sites with 72 grazed sites in varying states of modification, which confirmed the suggestions from the Murchison River catchment survey. Pringle (1994a) found that the most sensitive indicator of grazing impact was the prominence of key decreaser species and to a lesser extent increaser species. The decreaser species included *Atriplex bunburyana, A. vesicaria, Chenopodium gaudichaudianum, Enchylaena tomentosa, Maireana atkinsiana, M. georgei* and *M. platycarpa.* Increaser species

included *Senna artemisioides* subsp. *filifolia, Eremophila malacoides, Acacia victoriae* and *Hakea preissii*. It appears that *Lawrencia squamata* is also an increaser. Pringle (1994a) found that the extent of cryptogamic crusting of the soil surface was significantly lower at grazed sites than at reference sites, which probably increases susceptibility to soil erosion (Tongway and Greene 1989, Tongway 1994).

Nature conservation

PXHS occurs on Goongarrie National Park in the north-eastern Goldfields and on Mt Elvire station, which was acquired by the Department of Conservation and Land Management in May 1991. It is distinctive of the inland, endoreically drained semi-arid southern shrubland. *Acacia speckii* (P3) was recorded at one site.

Gradational associations

PXHS grades upslope into *Maireana pyramidata*-dominated communities (e.g. PSAS) and downslope into *Frankenia* (FRAN), *Atriplex vesicaria* (BLSS) or samphire (SAMP) communities. In most cases the gradation involves a decline in the spatial heterogeneity of plant communities so characteristic of intact PXHS.

Land systems

Mainly palaeodrainage systems, Carnegie and Mileura; also tributary systems including Ero, Steer and Yewin.

22. Samphire flat (SAMP)

Sampling 11 inventory sites

General information

SAMP is characterised by the dominance of *Halosarcia* species on highly saline and often gypsiferous soils prone to waterlogging in the lowest parts of catchments; usually adjacent to bare salt lake beds. It was described in both the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) surveys.

Physiognomy and composition of vegetation

SAMP is almost always a scattered (10-20% projected foliar cover) low shrubland to less than 60 cm high. A sub-ordinate mid shrub stratum was recognised at 3 of 11 sites and a perennial grass stratum was recorded once.

Halosarcia species include *H. doleiformis, H. halocnemoides, H. indica, H. pterygosperma* and *H. undulata.* Other species commonly recorded include *Frankenia* spp. and *Gunniopsis quadrifida.*

Fifty-seven species were recorded at the 11 inventory sites at an average of 8 per site, half the survey species richness average. This indicates the very distinctive physical environment that is tolerated by a small number of species physiologically adapted to waterlogging and high salinity and often gypsum. SAMP does not really have an unique flora, rather it does not support many of the more widely distributed chenopod species.

Patterns of grazing impact

SAMP supports vegetation with saline foliage that is not readily grazed by stock unless water supplies are particularly fresh and there is not much else to graze. Presumably some of the more palatable species that make up a very minor and often peripheral part of SAMP can be grazed out. These species include *Atriplex vesicaria, Maireana amoena* and *M. atkinsiana*. Rarely one encounters fence-lines in which samphires have been grazed out on one side. This may be a result of poor fence siting rather than enormous numbers of stock. Soils are generally stable.

Gradational associations

SAMP grades upslope into *Frankenia* (FRAN), *Atriplex vesicaria* (BLSS) or *Plain mixed halophyte shrubland* (PXHS) as *Halosarcia* species become less prominent and soils become less prone to waterlogging, less saline and less gypsiferous.

Land systems

Mainly Carnegie; also Hootanui, Mileura and Yewin.

23. Sandy bank lake shrubland (SBLS)

Sampling 11 inventory sites

General information

SBLS was first described in the north-eastern Goldfields survey (Pringle 1994a). It is characteristic of the inland southern shrubland rangelands, occurring with varying degrees of development and regularity of pattern on alluvial plains surrounding salt lakes. While wind and water may have transported the sand into the area, the banks probably form as result of high energy sheet flow processes, as alignment, where recognisable, is usually related to the slope of the land rather than prevailing wind directions. Soils are generally red sands, occasionally being duplexes on lower banks.

Physiognomy and composition of vegetation

SBLS consists of a sclerophyll component associated with non-saline, coarse-textured soils and a chenopod component associated with texture contrast (duplex) soils. The sclerophyll component appears to be more prominent on higher banks, while chenopods predominate on lower banks and bank margins. This variability is reflected in the wide range of states in which the vegetation may be observed.

SBLS usually supports a scattered to moderately close (15-25% projected foliar cover) shrub and tree component with a subordinate perennial grass component. The tall shrub stratum was generally dominant, with low and mid shrubs prominent and perennial grass and tree strata less common, but occasionally dominant.

Perennial grasses appear to be less conspicuous in this area than in the north-eastern Goldfields, possibly reflecting the greater dominance and reliability of winter growth seasons, particularly in the south and west. This winter dominance would favour shrubs over grasses in the competition for ecological space.

While SBLS is rich in species, its flora is very common in other habitats; 80 species were recorded at the 11 inventory sites at an average of 19 per site.

The following species (by strata) are dominant and/or common:

Trees:	Not usually a recognisable stratum; *Acacia aneura* frequent.
Tall shrubs:	Dominant – very variable; usually *Acacia* spp. Common – *A. aneura, A. acuminata* subsp. *burkittii, A. ramulosa, A. tetragonophylla, Dodonaea lobulata subsp. angustissima, Eremophila miniata, Exocarpos aphyllus* and *Hakea preissii* (KI).
Mid shrubs:	Dominant – very variable. Common – *Senna artemisioides* subsp. *filifolia* (KI), *Eremophila forrestii* and *Scaevola spinescens.*
Low shrubs:	Dominant – very variable. Common – *Atriplex bunburyana* (KD), *A. vesicaria* (KD), *Senna artemisioides* subsp. *filifolia* (KI), *Enchylaena tomentosa* (KD), *Eremophila forrestii, Frankenia* spp., *Gunniopsis quadrifida, Maireana georgei* (KD), *M. pyramidata, M. thesioides* (KD), *M. triptera, Ptilotus obovatus, Rhagodia drummondii, Solanum orbiculatum* (KI).
Perennial grasses:	Dominant – stratum present at less than half of sites. Common – *Monachather paradoxa* (KD), *Stipa elegantissima.*

Patterns of grazing impact

Grazing impacts are likely to affect the mix and abundance of palatable low shrubs including *Atriplex* and *Maireana* spp. and may also result in a decline in *Monachather paradoxa.* These changes may allow a secondary succession involving increased species such as *Hakea preissii* and *Solanum orbiculatum*. In the Murchison River catchment survey, *Eriachne helmsii* was found to succeed more palatable 'wanderrie' grasses (e.g. *Monachather paradoxa*). Soil erosion is not generally a problem.

Nature conservation

SBLS occurs on Mt Elvire station, which was acquired by the Department of Conservation and Land Management in May 1991. Its flora is a mix of widely distributed chenopod and sclerophyll species. Rabbits sometimes build warrens in this country and can cause severe degradation to this and surrounding habitats. Their control in the north of Mt Elvire's lake country will contribute to the maintenance of conservation values in that area.

Gradational associations

SBLS is distinctive in its mix of chenopod and sclerophyll habitat species. The sandy banks are usually clearly defined and gradations into adjacent chenopod low shrubland habitats are usually minimal. Chenopods are often more prevalent on the edges of larger, higher banks than on their tops.

Land systems

Mainly Carnegie; also Joy, Roderick and Skipper.

24. Silver saltbush shrubland (SSAS)

Sampling 21 inventory sites and 4 condition sites

General information

SSAS was described as part of *Saltbush Shrubland* in the Murchison River catchment survey (Curry *et al.* 1994) and in its own right in the north-eastern Goldfields survey (Pringle 1994a). SSAS is named after *Atriplex bunburyana* (silver saltbush), which is dominant or nearly so in intact habitat. Although SSAS occurs in salt lake country, it is far more extensive in tributary drainage land systems such as Ero and Wilson, occurring on less saline soils, which are characteristically deep (> 60 cm) texture contrast (duplex) types over hardpan and are not as prone to waterlogging. It is quite possible that tributary alluvial plains now dominated by *Maireana pyramidata* were once *A. bunburyana* plains and that many of the bare, severely degraded and eroded flats flanking major creek systems were also once *A. bunburyana* dominated shrubland. This is so in reference (lightly grazed or undeveloped) areas (Pringle 1994a, observations in this survey). SSAS occurs in small areas throughout the survey.

Physiognomy and composition of vegetation

Intact SSAS usually consists of very scattered to moderately close (10-25% projected foliar cover) low shrubland with a subordinate mid shrub stratum and less common tall shrubs and trees. Perennial grass strata are rarely present. Eighty-five species were recorded at the 21 inventory sites at an average of 13 species per site; slightly lower than the survey average of 16. Almost all species are common in other similar habitats.

The following species (by strata) are dominant and/or common:

Trees:	Rarely present.
Tall shrubs:	Dominant – acacias, but never a very well developed stratum. Common – *Acacia acuminata* subsp. *burkittii, A. tetragonophylla, Exocarpos aphyllus.*
Mid shrubs:	Dominant – no common species, stratum was recorded at 13 of 21 sites. Common – *Atriplex bunburyana* (KD), *M. pyramidata, Rhagodia eremaea.*
Low shrubs:	Dominant – *Atriplex bunburyana* (KD) or *Maireana pyramidata.* Common – *Enchylaena tomentosa* (KD), *Frankenia spp., Maireana georgei* (KD), *M. triptera, Ptilotus obovatus, Rhagodia eremaea, Solanum lasiophyllum.*

Perennial grasses:	Dominant – stratum rarely present. Common – *Stipa elegantissima.*

Patterns of grazing impact

SSAS is one of the most frequently degraded habitats in the arid southern shrubland of Western Australia (e.g. Curry *et al.* 1994, Pringle *et al.* 1994) because it supported productive nutritious pastures and grew in tributary drainage tracts with generally easily accessible fresh water supplies for stock. It was usually one of the first habitats targeted for pastoral production in areas being developed (Curry *et al.* 1994). Much SSAS is now severely degraded and eroded with subsoil exposure and scalding common. In such areas, mobile accumulations of sand support seasonal growth of ephemeral species creating colourful contrasts with more extensive stripped surfaces. SSAS may be considered to be an extensively desertified habitat.

Where modification appears more recent and usually considerably less severe, *A. bunburyana* has been succeeded by less palatable and more resilient species such as *M. pyramidata* and *Ptilotus obovatus*, sometimes accompanied by invasion of *Hakea preissii*. In runs of good seasons *Maireana triptera* and *Solanum lasiophyllum* may proliferate.

Nature conservation

SSAS is one of the habitats most threatened by pastoralism in the arid shrubland, yet remains inadequately reserved.

Gradational associations

It is a distinctive habitat often grading into more heterogeneous chenopod communities on more saline soils.

Land systems

Mainly Carnegie, Ero and Mileura.

25. Drainage tract acacia shrubland/woodland with chenopod understorey (DACS)

Sampling 7 inventory sites

General information

DACS was first described (as a ‘mulga’ rather than ‘acacia’ habitat – DMCS) in the adjacent north-eastern Goldfields rangeland survey (Pringle 1994a). It is not extensive, occurring as drainage corridors carrying flow from uplands towards salt lakes through alluvial plains. It is usually flanked by chenopod low shrubland on alluvial plains with texture contrast (duplex) soil types. DACS usually has deeper, sometimes heavier textured soils than the flanking plains, underlain by hardpan.

It occurs most commonly in the north-eastern (Eremaean) part of the survey area on the Kirkalocka, Youanmi and Sandstone 1:250,000 scale map sheets. Towards the South-West Botanical Province eucalypts comprise the overstorey in many concentrated drainage tracts.

Physiognomy and composition of vegetation

DACS varies considerably according to the level of development in the overstorey, ranging from very scattered to close (10-50% projected foliar cover) shrubland, dominated often by the tall shrub (occasionally tree) stratum, but not uncommonly by the low shrub layer where the sparseness of the upperstorey allows. Mid shrubs and perennial grasses are not usually conspicuous.

Forty-nine species were recorded at the seven inventory sites, at an average of 15 species per site; approximately the survey average. The flora is common to many other habitats, consisting of a mix of species associated with a wide range of sclerophyll or chenopod-dominated habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Acacia aneura.* Common – *Eremophila longifolia.*
Tall shrubs:	Dominant – variable; acacias. Common – *A. aneura, A. acuminata* subsp. *burkittii, A. tetragonophylla, Hakea preissii* (KI).
Mid shrubs:	Dominant – variable when present. Common – *Maireana pyramidata, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – variable. Common – *Atriplex bunburyana* (KD), *Enchylaena tomentosa* (KD), *Eremophila maculata, Maireana pyramidata, Ptilotus obovatus, Rhagodia eremaea, Scaevola spinescens, Solanum lasiophyllum.*
Perennial grasses:	Dominant – rarely present as a stratum. Common – *Stipa elegantissima.*
Other common plants:	*Amyema* spp. (mistletoes), *Marsdenia australis* (climber).

Patterns of grazing impact

Palatable understorey species including *Atriplex bunburyana* and *Enchylaena tomentosa* can be removed under sustained heavy grazing, possibly to be replaced by less palatable, invasive species including *Hakea preissii, Maireana triptera* and *Solanum orbiculatum.*

Nature conservation

DACS is not common, but may provide refuge for a variety of fauna in otherwise often shelterless chenopod plains. It appears to be a preferentially grazed habitat.

Gradational associations

The overstorey is usually confined to the concentrated drainage tract, while understorey floristics often resemble adjacent chenopod shrubland.

Land systems

Mainly tributary systems including Ero and Tindalarra.

Other minor habitats in 'alluvial plain with conspicuous chenopod shrubland habitat' group

Frankenia low shrubland (FRAN)
– 1 inventory site

FRAN was described as a type of *Mixed Halophytic Shrubland* in the Murchison River catchment survey (Curry *et al.* 1994) and in its own right in the north-eastern Goldfields survey (Pringle 1994a). FRAN usually occurs in saline alluvial tracts near salt lakes, in association with samphire (SAMP) and *Atriplex vesicaria* (BLSS) communities. It occurs as very scattered to scattered (5-15% projected foliar cover) low shrubland, is dominated by *Frankenia* spp., often in association with *A. vesicaria, Gunniopsis quadrifida, Halosarcia* spp. and *Maireana* spp.

Mixed chenopod shrubland with mulga overstorey (MHHS) – 3 inventory sites

MHHS was described in the north-eastern Goldfields survey (Pringle 1994a). It occurs as a transitional habitat between chenopod low shrubland around salt lakes and *Acacia aneura* tall sclerophyll shrubland on alluvial sheet flood plains upslope. *Maireana pyramidata* is often the dominant low shrub with *A. aneura* in subordinate tall shrub or tree strata.

Plain oldman saltbush shrubland (POMS)
– 2 inventory sites

Two outlier mid shrubland communities of *Atriplex nummularia* (old man saltbush) dominated habitat were encountered on alluvial plains derived from Windimurra complex gabbros on Windimurra station. *A. nummularia* is usually found south-west of Lake Barlee in greenstone-dominated terrain in the Goldfields and on the Nullarbor Plain limestone karst landscape. POMS included more common chenopod species including *A. vesicaria* and *Maireana pyramidata* and one site had sparse *Eragrostis setifolia* in the ground layer. *A. nummularia* was noticeably sparse on the degraded side of a fence-line.

E. CALCRETE OR KOPI ASSOCIATED SHRUBLAND OR WOODLAND HABITATS

These habitats are generally confined to salt lake systems and surrounds. They form where either groundwater has evaporated to form calcrete platforms and undulating plains, or gypsiferous sediments (kopi) have been blown off deflated lake beds and become stabilised as dunes around lake margins. In some cases kopi dunes form on extensive lake beds (e.g. on Lake Noondie). Both calcrete and gypsum are transported in solution from regional catchments down to salt lakes, where they are concentrated by evaporation (Jacobson 1988). While kopi dunes are characteristic of salt lake systems, calcrete platforms also occur in river systems such as in the upper Murchison River catchment (Curry *et al.* 1994).

Calcrete platforms are found low in the landscape, often within the alluvial plains surrounding salt lakes. They support a distinctive range of species including Casuarina pauper (black oak) pictured above in CCAS habitat. Calcrete habitats have attracted the interest of mining companies as they have occasionally accumulated uranium leached out of granites higher in the landscape.

26. Calcrete platform woodland (CAPW)

Sampling 6 inventory sites

General information

CAPW was first described in the north-eastern Goldfields rangeland survey (Pringle 1994a). It is most common in the centre and north-east (Eremaean) parts of the survey area. It consists of platforms or undulating rubble-covered plains to 5 m in relief. Soils are very shallow (<30 cm), highly calcareous and alkaline.

Physiognomy and composition of vegetation

CAPW generally occurs as scattered (10-20% projected foliar cover) low woodlands with subordinate tall, mid and low shrub strata in varying degrees of development. Perennial grasses are not usually conspicuous, however the facultative biennial *Stipa nitida* can survive runs of good seasons, forming a dense ground layer that increases the risk of wildfire on drying out.

Forty-two species were recorded at the six inventory sites at an average of 14 species per site, marginally below the survey average. Species are common in other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – variable, *Casuarina pauper* or eucalypts. Common – *C. cristata, Eremophila longifolia, Eucalyptus striatycalyx.*
Tall shrubs:	Dominant – *Acacia acuminata* subsp. *burkittii.* Common – *A. tetragonophylla, A. victoriae* (KI), *Exocarpos aphyllus.*
Mid shrubs:	Dominant – *Senna artemisioides* subsp. *filifolia* (KI). Common – *Lycium australe, Rhagodia eremaea, Scaevola spinescens.*

Low shrubs:	Dominant – *S. artemisioides* subsp. *filifolia* (KI) or *Ptilotus obovatus* (KD). Common – *Enchylaena tomentosa* (KD), *M. pyramidata, M. trichoptera, M. triptera, Pimelia microcephala, Rhagodia drummondii, R. eremaea, Scaevola spinescens, Solanum lasiophyllum*.
Perennial grasses:	Common – *Stipa elegantissima.*

Annual grasses such as *Enneapogon caerulescens* and *Stipa nitida*, and forbs, particularly *Sclerolaena* species, are seasonally abundant.

Patterns of grazing impact

Herbage sought by stock, feral goats and kangaroos make it a preferentially grazed habitat. Assessing grazing impacts is difficult because of the high degree of natural variability in the understorey. The absence of perennial chenopod shrubs does not necessarily indicate degradation, however the absence of *Ptilotus obovatus* would strongly suggest past overgrazing. Overgrazing is also likely to result in the decline (where present) of species such as *Enchylaena tomentosa* and *Maireana georgei*. It is not known whether the general absence of young overstorey species is due to grazing or recruitment being rare and episodic.

Nature conservation

CAPW is a preferentially grazed habitat of minor extent in this survey area. The build-up of annual grasses can pose a threat of fire in a habitat whose perennial shrubs are not adapted to it.

Gradational associations

CAPW grades into *Acacia acuminata* subsp. *burkittii* tall shrubland (JAMS) with the decline in the tree stratum and into *Plain eucalypt chenopod woodlands* (PECW) as soil depth increases and the chenopod understorey becomes more conspicuous. *Calcareous casuarina/acacia shrubland or woodland* (CCAS) is floristically similar, but occurs on alluvial plains, has deeper soil and more uniform, denser vegetation.

Land systems

Cunyu and Mileura.

27. Calcrete platform jam shrubland (JAMS)

Sampling 12 inventory sites

General information

JAMS is named after its dominant tall shrub species *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) and is described for the first time. It occurs on calcrete platforms similar to CAPW, but often with an even shallower soil (< 20 cm) with much calcrete outcrop. Like CAPW, it occurs in the trunk valleys of palaeodrainage axes which have become choked by the precipitation of calcium carbonate from groundwater through capillary driven evaporation (Jacobson 1988). It is associated with the northern and eastern (palaeodrainage) parts of the survey area.

Physiognomy and composition of vegetation

JAMS occurs as scattered to moderately close (10-30% projected foliar cover) tall (occasionally low) sclerophyll shrubland, with a subordinate mid shrub stratum and occasional trees and perennial grasses.

Eighty-four perennial species were recorded at 12 inventory sites at an average of 18 per site, a little higher than the survey average. Almost all species are common elsewhere.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – occasionally *Casuarina pauper.* Common – *Acacia aneura.*
Tall shrubs:	Dominant – invariably *A. acuminata* subsp. *burkittii.* Common – *A. aneura, A. tetragonophylla, Exocarpos aphyllus, Eremophila longifolia.*
Mid shrubs:	Dominant – recorded at half sites; no species common. Common – *Senna artemisioides* subsp. *filifolia* (KI), *Lycium australe*, *Rhagodia eremaea* and *Scaevola spinescens.*
Low shrubs:	Dominant – variable if not *Ptilotus obovatus* (KD). Common – *Atriplex bunburyana* (KD), *S. artemisioides* subsp. *filifolia* (KI), *Enchylaena tomentosa* (KD), *Lycium australe, Maireana georgei* (KD), *M. trichoptera* (facultative biennial), *M. triptera, P. obovatus* (KD), *Rhagodia drummondii, R. eremaea, Scaevola spinescens, Solanum lasiophyllum, S. orbiculatum.*
Perennial grasses:	Dominant – stratum rarely present. Common – *Stipa elegantissima.*

Annual species including *Sclerolaena* spp. and *Stipa nitida* and *Enneapogon caerulescens* are abundant in good seasons.

Patterns of grazing impact

The understorey appears to be naturally very variable, probably reflecting different degrees of soil development from being sparse on shallow soils and denser and richer on better developed, deeper soils. The absence of *Ptilotus obovatus* and perhaps proliferation of species such as *Senna artemisioides* subsp. *filifolia* and *Solanum orbiculatum* may well indicate previous overgrazing. These often rubbly soils are generally stable and often have an extensive, healthy cryptogamic crust.

Nature conservation

JAMS is a preferentially grazed habitat not well represented in nature reserves in this region.

Gradational associations

JAMS grades into *Calcrete platform woodland* (CAPW) on calcrete platforms where trees become more prominent and the tall shrub stratum becomes subordinate.

Land systems

Mainly Cunyu; also Carnegie and Mileura.

Other minor habitats in the 'calcrete or kopi associated shrubland or woodland habitat' group

Calcareous casuarina acacia shrubland or woodland (CCAS) – 3 inventory sites

CCAS was first described in the north-eastern Goldfields (Pringle 1994a), where it was a major habitat in the southern third of the area. It is largely restricted to the far south-east of this survey. It occurs as very gently undulating to nearly level plains near salt lakes with shallow (<60 cm) calcareous loams over calcrete, often with a light soil mantle of calcrete rubble. CCAS occurs as a scattered to moderately close acacia tall shrubland with a sparse *Casuarina* tree layer, or more frequently, as a low *Casuarina* woodland with a prominent acacia tall shrub stratum. Cover is considerably more uniformly distributed than in CAPW, in which trees are noticeably clumped. CCAS is characteristic of Deadman land system.

Kopi dune or plain woodland (KOPI) – 3 inventory sites

KOPI was first described in the north-eastern Goldfields survey (Pringle 1994a). It occurs as dunes and undulating banks of wind blown gypsiferous sediments on and adjacent to salt lake beds. It is characteristic of the salt lake-drained interior of Western Australia and supports a very scattered to scattered (5-15% projected foliar cover) vegetation often dominated by *Eucalyptus striatycalyx* (kopi gum) and with an understorey characteristically including L*awrencia helmsii, Lycium australe, Maireana pentatropis, Sclerolaena fimbriolata* and *Zygophyllum* sp.

F. DRAINAGE FOCUS SCLEROPHYLL HABITATS

This group of habitats usually occurs as small drainage termini in the lowest parts of the landscape; in and adjacent to salt lake systems. Making up a very small proportion of the survey area, these fertile patch habitats are distinctive and may prove to have particular conservation value as fauna habitat (Morton and Stafford Smith 1994). This value may peak in very good seasons (breeding seasons) and warrant special management such as reducing stocking rates plus feral cat and fox control.

28. Melaleuca swamp shrubland (MESS)

Sampling 11 inventory sites

General information

MESS usually occurs as swamps on alluvial plains adjacent to salt lakes and their tributary systems, but may occur anywhere where drainage is locally concentrated, particularly if there is calcrete in the subsoil. It usually occurs as densely vegetated drainage foci, or as fringing vegetation to claypans, into which it sometimes extends. It occurs throughout the survey area.

Physiognomy and composition of vegetation

MESS occurs either as very scattered to scattered (5-15% projected foliar cover) tall shrubland on claypans and or as moderately close to close (25-50% projected foliar cover) tall shrubland in swamps and surrounding claypans. The mid shrub stratum is usually well developed and often contains many juvenile *Melaleuca* plants. Trees, low shrubs and perennial grasses are usually only a minor component.

Forty-five species were recorded at the 11 inventory sites at a relatively low average of eight species per site; approximately half the survey average. Swamps are peculiar habitats and not surprisingly, the generalist species that characterise most habitats are not able to establish in MESS. While many common species are not found, the flora is still not particularly unique, rather, a small subset of the widely spread species.

The following species (by strata) are dominant and/or common:

Trees:	Not common.
Tall shrubs:	Dominant – *Melaleuca* spp., particularly *M. uncinata.* Common – *Acacia acuminata* subsp. *burkittii, A. tetragonophylla* and *Melaleuca sheatheana.*
Mid shrubs:	Dominant – variable, often young *Melaleuca* spp. Common – *M. uncinata, Scaevola spinescens.*
Low shrubs:	Dominant – variable where stratum is present. Common – *Frankenia* spp.
Perennial grasses:	Dominant – rarely present, sometimes on claypans, varied species. Common – *Stipa elegantissima.*

Patterns of grazing impact

Not much is known about the grazing ecology. Feral goat damage to *Melaleuca* spp. was observed. Where a chenopod understorey occurs, one might expect a decline in species such as *Atriplex bunburyana* and *Enchylaena tomentosa* under excessive grazing pressure.

Nature conservation

MESS may be an important fauna habitat as an ephemeral wetland. To this end, it may fit into the Restricted Use Unit

category of Morton and Stafford Smith (1994). These are areas whose conservation value peaks under certain conditions (in this case excellent seasons) and may require special management at such times. This may include reducing stocking rates and feral cat and fox control if animals are breeding.

Gradational associations

MESS is a fairly distinctive and well defined habitat. It may resemble *Acacias with claypan grass understoreys* (ACGU) on some claypans supporting a mix of melaleuca shrubs and tussock grasses (e.g. *Eriachne flaccida*).

Land systems

Cunyu, Ero, Marlow, Melaleuca, Mileura, Pindar and Racecourse.

29. Acacias with claypan grass understorey (ACGU)

Sampling 9 inventory sites

General information

ACGU is quite common but rarely exceeds a hectare in extent. It occurs in concentrated tributary drainage systems and on claypans in the centre and north-east of the survey area. It may occur as a tussock grassland with scattered shrubs, or as drainage foci with tussock grasses surrounded by tall shrubs. Soils are usually deep (>1 m) clays, which may be cracking.

Physiognomy and composition of vegetation

The shrub component is either very scattered (<5% projected foliar cover) in tussock grassland narrow drainage tracts, or scattered to moderately close (15-30%) around the margins of tussock grassland drainage foci or in concentrated drainage tracts. The tussock grass layer rarely exceeds 5% basal area. Annual grasses are abundant in good summer seasons.

Fifty-seven species were recorded at the 9 inventory sites, at an average of 13 per site, slightly lower than the survey average of 16. Most species are common to other habitats, however few other habitats support a tussock grassland on heavier textured soils (e.g. *Gilgai grassy low shrubland* – GGLS). The combination of an acacia upper storey and a tussock grass layer on heavier textures soils makes ACGU distinctive.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – occasionally *Acacia aneura.* Common – *A. aneura, Eremophila longifolia, Pittosporum phylliraeoides.*
Tall shrubs:	Dominant – variable; *A. tetragonophylla* most often. Common – *A. aneura, A. tetragonophylla, E. longifolia, Exocarpos aphyllus* and *Hakea preissii.*
Mid shrubs:	Dominant – variable. Common – *A. tetragonophylla, Senna glutinosa* subsp. *chatelainiana* (KD), *Ptilotus divaricatus, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – very variable. Common – *Ptilotus obovatus, Rhagodia eremaea, Scaevola spinescens* and *Solanum lasiophyllum.*
Perennial grasses:	Dominant – *Eriachne flaccida* or *Eragrostis* spp. Common – *Eragrostis setifolia, Eriachne flaccida, Stipa elegantissima.*
Other plant forms:	*Amyema* and *Lysiana* spp. (mistletoes).

Patterns of grazing impact

The grazing ecology has not been investigated in any detail in this region. In the Ashburton River catchment survey *Eragrostis setifolia* was found to be a preferentially grazed species that was rare in degraded situations (Payne *et al.* 1988). *Eriachne flaccida* appears to be much less attractive to stock in this area and vigorous populations were sometimes observed close to water points. Mitchell and Wilcox (1994) however consider it to be a sensitive decreaser. Under excessive grazing pressure one might expect a decline in palatable low shrubs including *Maireana* spp. and perhaps *Ptilotus obovatus*. Soils appear to be inherently stable.

Nature conservation

ACGU represents small, particularly fertile patches in the landscape that are likely to be preferentially grazed in good seasons when annual grasses and forbs are abundant. It is not known how this would affect the habitat available to native fauna. These areas are both scattered and small, which makes their individual specific management difficult. ACGU occurs on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.).

Gradational associations

ACGU grades into *Drainage tract acacia shrubland* (DRAS) as the upper storey thickens, tussock grasses decline and soils become loamier.

Land systems

Carnegie, Cunyu, Ero, Marlow and Mileura; occasionally in Nallex and Naluthanna.

Other minor habitats in the ‘drainage focus sclerophyll habitat’ group

Plain drainage focus thicket (PDFT) – 3 inventory sites

PDFT occurs often as near circular drainage foci, rarely attaining a hectare in size and supporting a dense tall

shrubland or woodland vegetation contrasting strongly with adjacent broad plains of scattered chenopod shrubland. It occurs most frequently on alluvial plains fringing salt lakes and tributary drainage systems; most characteristically in Steer land system. It is most common in the north-eastern (Eremaean) part of the survey area. Vegetation is often close (> 30% projected foliar cover) and consists of species common to a number of other habitats. Common species include *Acacia aneura, A. tetragonophylla, Amyema* spp. (mistletoes), *Enchylaena tomentosa, Eremophila longifolia, Lycium australe, Porana* sp. (creeper), *Ptilotus obovatus, Pittosporum phylliraeoides, Rhagodia eremaea, Solanum lasiophyllum* and *Stipa elegantissima*. PDFT is a fertile patch and animal shelter habitat and usually supports a rich ground dwelling invertebrate fauna. *Spartothamnella puberula* (P2) was recorded.

Cane grass swamp (CGSW)
– 1 inventory site

Cane grass swamps are rare and usually small (<0.5 ha). There is a very large example of approximately 1.2 km across on Windimurra station. *Eragrostis australasicus* (cane grass) dominates these communities, sometimes with other perennial grasses such as *Eragrostis setifolia* and shrubs including *Atriplex amnicola* and *Muehlenbeckia cunninghamii* (lignum). It is probably an important fauna habitat. CGSW is most commonly encountered in the upper parts of palaeodrainage systems such as Carnegie and Mileura land systems.

Lignum swamp (LISW)

Muehlenbeckia cunninghamii (lignum) is the dominant shrub in non-saline drainage foci that are regularly subjected to flooding (Mitchell and Wilcox 1994) and forms reasonably uniform stands sometimes exceeding 50% projected foliar cover. It generally occurs in the upper sectors of palaeodrainage systems such as Carnegie and Mileura and does not usually support many other plants.

G. BROAD SHEET FLOOD HARDPAN PLAIN SCLEROPHYLL SHRUBLAND OR WOODLAND HABITATS

These habitats are common throughout the arid shrubland of Western Australia, extending from the inland Pilbara in the north to Menzies in the south and across to the wheatbelt and coast further north (Teakle 1936). While *Acacia aneura* dominates most of these habitats, other acacias are more prominent approaching the South-West Botanical Province (Beard 1991). These acacias include *Acacia acuminata* subsp. *burkittii, A. grasbyi* and *A. ramulosa.*

Soils tend generally to be shallow (< 60 cm deep) red clay loams over hardpan and occur on broad, nearly level alluvial plains subject to intermittent sheet flooding. While clays in the upper soil profiles are sometimes dispersive, cryptogamic crusts appear to retard their removal in sheet flows. General flatness also helps maintain soil stability.

Redistribution of litter and nutrients to obstacles hindering sheet flow is an important process that provides a mosaic of fertile patches for plant establishment and poorer, run-off areas between (Hacker 1979, Tongway *et al.* 1989, Tongway and Ludwig 1990).

The major human modifications to these habitats have been due to pastoral management; the running of livestock (mainly sheep) and localised cutting of *Acacia aneura* for fence posts and for the mining industry. Curry et al. (1994) compared the data from 30 reference sites with the data from grazed sites in the Murchison River catchment and found that the sites in the undeveloped areas showed significantly greater perennial shrub density and species richness, which was related primarily to differences in palatable species and was reflected in higher diversity (Shannon Weiner Index).

Trends towards conservative stocking strategies and range monitoring have probably reversed some of the changes. Observations of destocked areas clearly indicate that these habitats can respond to destocking, with minimal management intervention required as long as a seed source remains. This resilience is partly due to the inherent stability of the soil resource. These habitats do not collapse as easily as chenopod shrubland habitats on fragile duplex soils.

Acacia aneura (mulga) trees emerge over Acacia ramulosa (bowgada) tall shrubland in MUBW, an extensive habitat in this survey area. In this case, Acacia grasbyi (miniritchie) is also common, typical of the western half of the survey area. Feral goats favour this type of habitat where there is abundant protective cover and the non-saline shrubs provide attractive grazing.

30. Hardpan plain mulga shrubland (HPMS)

Sampling 33 inventory and 1 condition site

General information

HPMS is one of the most widely distributed habitats in the arid zone of Western Australia (Payne *et al.* 1988, Wilcox and McKinnon 1972, Curry *et al.* 1994, Pringle 1994a). It occupies transitional plains between erosional uplands and salt lake systems in substantially bevelled landscapes characteristic of antiquity. After major rainfall events these plains, which rarely attain a slope of 1%, are subject to low energy sheet flows. The soil is usually a shallow (<60 cm) clay loam over a ferrugino-siliceous hardpan and has a well developed cryptogamic crust. The roots of larger perennial plants successfully infiltrate breaks in the hardpan to acquire moisture.

HPMS occurs through most of the survey area, but is subordinate in extent to *Hardpan plain acacia shrubland*

(HCAS) towards the wheatbelt and South-West Botanical Province (Beard 1991). It was the most frequently (1,442 times) recorded habitat type in the traverse record.

Physiognomy and composition of vegetation

HPMS is usually a scattered to moderately close (10-30% projected foliar cover) tall shrubland or low woodland with well developed low and mid shrub strata. Cover in this survey area appears to be slightly higher than in the north-eastern Goldfields which may reflect better and more reliable winter seasons.

One hundred-and-ten species were recorded at the 33 inventory sites at about the survey average of 16 species per site. Species common to HPMS are also common in other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Acacia aneura.* Common – no other common species.
Tall shrubs:	Dominant – *A. aneura*, occasionally other acacias. Common – *A. acuminata* subsp. *burkittii, A. craspedocarpa, A. grasbyi, A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable, *Acacia* or *Eremophila* spp. Common – *Acacia ramulosa, A. tetragonophylla, Senna glutinosa* subsp. *charlesiana, Eremophila forrestii, E. latrobei* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – very variable, *Ptilotus obovatus* most common. Common – *Eremophila forrestii, E. latrobei* (KD), *Maireana convexa* (KD), *M. thesioides* (KD), *P. obovatus, Rhagodia eremaea, Sida calyxhymenia* (KD), *Solanum lasiophyllum, Spartothamnella teucriflora* (KD).
Perennial grasses:	Dominant – rare as a recognisable stratum. Common – *Monachather paradoxa* (often as a facultative biennial), *Stipa elegantissima.*
Other common plant forms:	*Dianella revoluta* (lily).

Patterns of grazing impact

The grazing ecology of HPMS was investigated in some detail in the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) rangeland surveys. Grazing reduces the density and number of palatable understorey shrubs. This decline may sometimes lead to greater density of one or two unpalatable species such as *Eremophila gilesii* or *E. georgei.* Hacker (1979, 1984a,b) noted that palatable low shrubs were often removed first and more easily from open areas rather than from under existing clumps of overstorey species. The overstorey itself is rarely adversely affected except in exceptionally degraded situations where soil sealing retards water infiltration. Most mulga deaths are more likely attributable to the synergy of age and disturbances such as hail storms, grubs or drought.

Nature conservation

A combination of low palatable perennial shrub density and easily accessible fresh stock water supplies has resulted in widespread modification of botanical composition. Due to low slopes, the diffuse nature of overland flow and the natural predominance of unpalatable species, it appears that ecological processes continue to operate in most degraded areas. HPMS occurs in Wanjarri Nature Reserve (Pringle 1995b, Pringle *et al.* in prep.) in the adjacent north-eastern Goldfields.

Gradational associations

HPMS grades into *Hardpan plain acacia shrubland* (HCAS) in the south and west of the survey area where acacias other than *A. aneura* dominate and into *Hardpan plain mulga and bowgada shrubland or woodland'* (MUBW) on deeper soils supporting *A. ramulosa* tall shrubs and large *A. aneura* trees.

Land systems

In many systems either as a minor, peripheral unit (e.g. Challenge) or as the major unit (e.g. Rainbow or Tindalarra).

31. Hardpan plain acacia shrubland (HCAS)

Sampling 30 inventory sites

General information

HCAS is a south-western version of HPMS, having a floristically more variable upper storey, which also tends to be a little denser. It occurs on nearly level sheet flood plains with shallow (<60 cm) clay loams over a ferrugino-siliceous hardpan. As with HPMS, overland flow is an important landscape process which, if disrupted, can cause water starvation and consequent shrub deaths.

Physiognomy and composition of vegetation

HCAS usually occurs as a scattered to moderately close (15-30% projected foliar cover) tall shrubland with well developed low and mid shrub strata. Trees and perennial grasses rarely form a recognisable stratum. One hundred and twenty-three species were recorded at the 30 inventory sites at 17 species per site, about the survey average. Species common to HCAS are also common in other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – stratum infrequent. Common – *Acacia aneura.*
Tall shrubs:	Dominant – very variable; most commonly *Acacia ramulosa.*

	Common – *A. acuminata* subsp. *burkittii, A. aneura, A. grasbyi, A. ramulosa, A. tetragonophylla, Exocarpos aphyllus, Hakea recurva.*
Mid shrubs:	Dominant – variable; often acacias. Common – *Acacia ramulosa, A. tetragonophylla, Eremophila forrestii, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – very variable; *Ptilotus obovatus* at 8 sites. Common – *Eremophila forrestii, Maireana convexa* (KD), *Ptilotus obovatus, Rhagodia eremaea, Scaevola spinescens, Sida* aff. *virgata.*
Perennial grasses:	Dominant – very variable; usually poorly developed. Common – *Amphipogon* sp., *Monachather paradoxa* (often as a facultative biennial) and *Stipa elegantissima.*
Other common plant forms:	*Cheilanthes* sp. (fern) and *Dianella revoluta* (lily).

Patterns of grazing impact

Excessive grazing pressure is likely to lead to decline in palatable species such as *Eremophila latrobei* and *Maireana convexa* in the understorey. As in HPMS, much of the vegetation appears not to be affected substantially by grazing and hence ecosystem collapse is rarely observed. Soils are generally stable because of low slopes, diffuse run-on, substantial overstorey cover and cryptogamic crusting of the surface.

Nature conservation

HCAS is a major habitat in rangelands adjacent to the wheatbelt and not known to be present in any nature reserves. Its sparse palatable understorey species are susceptible to removal but often comprise only a small component of the vegetation.

Gradational associations

HCAS is most similar to *Hardpan plain mulga shrubland* (HPMS) but also grades into *Plain native pine woodland* (PINW) or *Sandplain acacia shrubland* (SACS) in areas receiving more diffuse run-on and with deeper, lighter textured soils.

Land systems

Most extensive in Tindalarra, Woodline and Yowie.

32. Hardpan plain mulga shrubland with scattered chenopods (HMCS)

Sampling 12 inventory sites

General information

HMCS was first described in the north-eastern Goldfields rangeland survey (Pringle 1994a). It often occurs as depositional lobes in the upper parts of alluvial plains and usually has shallow (< 60 cm deep) duplex or red earth soils on hardpan. It is found in pockets throughout most of the survey area except in the south, where *Eucalyptus loxophleba* woodlands dominate this part of the landscape.

Physiognomy and composition of vegetation

HMCS usually occurs as a scattered to moderately close (10-25% projected foliar cover) tall shrubland, occasionally with a dominant or co-dominant low shrub stratum. Mid shrubs are also common, however trees and perennial grasses are a very minor component if present. Seventy-one species were recorded at the 12 inventory sites at an average of 18 species per site, two more than the survey average. Species common to HMCS are also common in other habitats, the distinctive feature being its combination of a sclerophyll overstorey and a chenopod component in the understorey.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – stratum rarely present. Common – *Acacia aneura.*
Tall shrubs:	Dominant – *Acacia aneura* at half of the sites. Common – *A. acuminata* subsp. *burkittii, A. aneura, A. grasbyi, A. ramulosa, A. tetragonophylla, Exocarpos aphyllus.*
Mid shrubs:	Dominant – very variable. Common – *A. tetragonophylla, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – variable; *Ptilotus obovatus* at half of the sites. Common – *Atriplex bunburyana* (KD), *Enchylaena tomentosa* (KD), *Frankenia spp., Maireana convexa* (KD), *M. georgei* (KD), *M. pyramidata, M. thesioides* (KD), *M. triptera, P. obovatus, Rhagodia eremaea, Scaevola spinescens, Sida calyxhymenia, Solanum lasiophyllum, Spartothamnella teucriiflora* (KD).
Perennial grasses:	Dominant – stratum rarely observed. Common – *Stipa elegantissima.*

Patterns of grazing impact

Several palatable low shrubs are sensitive to grazing and are readily removed. These include *Atriplex bunburyana, Enchylaena tomentosa* and some *Maireana* spp. The natural sparsity of these species and the easy access to good supplies of fresh stock water means that many areas are now often devoid of the chenopod component or have an understorey dominated by *Maireana triptera*. Soils are susceptible to erosion where duplexes occupy concentrated drainage tracts. In these areas, erosion may lead to sealing and mulga deaths.

Nature conservation

This is a minor habitat which is preferentially grazed and susceptible to degradation. It is not known to occur on reserved lands. It was observed twice on Mt Elvire station, which was acquired by the Department of Conservation and Land Management in May 1991.

Gradational associations

Degraded HMCS closely resembles adjacent strictly sclerophyll dominated habitats when the chenopod understorey has been removed. Soil degradation may differentiate between degraded HMCS and other, more inherently stable communities such as *Hardpan plain mulga shrubland* (HPMS).

Land systems

Occurs in a variety of systems, most characteristically in Carnegie, Ero, Gransal, Sherwood, Tango and Tindalarra.

33. Drainage tract acacia shrubland (DRAS)

Sampling 50 inventory sites

General information

DRAS has been described previously in the adjacent north-eastern Goldfields survey (Pringle 1994a) as *Drainage mulga shrubland* (DRMS). 'Acacia' is preferred here in recognition of the prominence of acacias other than *A. aneura*, particularly *A. tetragonophylla*. It occurs in slightly lower sectors of broad hardpan sheet flood plains which are accordingly subjected to more concentrated run-on. Soils are generally deeper (>1 m) and heavier textured than adjacent sheet flood plains.

DRAS supports a rich invertebrate fauna using accumulations of litter and other detritus in this relatively fertile part of the landscape. Also indicative of this fertility is the well developed, often rough cryptogamic crusting of the soil surface. The common algae, crustose lichens and liverworts are often accompanied by mosses and foliose lichens in this habitat, which is the exception rather than the rule in this region. DRAS also provides shelter for larger animals and is common throughout the survey area.

Physiognomy and composition of vegetation

DRAS ranges from scattered to close (20-50%) tall shrubland, sometimes low woodland with understorey development inversely related to upper storey cover. The clear majority of sites had a moderately close to close (20-50% projected foliar cover) upper storey and a poorly developed understorey. One hundred and fifty-one species were recorded at the 50 inventory sites at an average of 14 species per site, two less than the average. Species common to DRAS are also common to other sclerophyll shrubland habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Acacia aneura.* Common – no other tree species commonly recorded.
Tall shrubs:	Dominant – acacias; most commonly *A. aneura, A. ramulosa* or *A. tetragonophylla.* Common – *A. acuminata* subsp. *burkittii, A. aneura, A. craspedocarpa, A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable; often acacias or *Eremophila* spp. Common – *A. acuminata* subsp. *burkittii, A. craspedocarpa, A. ramulosa, A. tetragonophylla, Eremophila latrobei* (KD), *Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – very variable; *Ptilotus obovatus* most common (16 sites). Common – *Abutilon cryptopetalum, Eremophila latrobei* (KD), *P. obovatus, R. eremaea, S. spinescens, Sida calyxhymenia, Solanum lasiophyllum, Spartothamnella teucriiflora* (KD).
Perennial grasses:	Dominant – occasionally *Eriachne flaccida* or *Stipa elegantissima.* Common – *S. elegantissima.*
Other common plant forms:	*Amyema* spp. (mistletoes).

Patterns of grazing impact

The understorey is highly variable, however, some palatable low shrubs such as *Eremophila latrobei* and *Ptilotus obovatus* are expected in most cases. As the palatable understorey shrubs are usually a minor component of this habitat, grazing impacts are minor and do not cause ecosystem collapse.

Nature conservation

DRAS may be an important habitat for native fauna. Its flora is not particularly distinctive. DRAS occurs in Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle 1995b, Pringle *et al.* in prep.).

Gradational associations

The vegetation most closely resembles *Hardpan plain mulga groves* (GRMU) and *Acacias with claypan grass understoreys* (ACGU). The former is developed by entrapment of nutrients and litter in sheet flow, while the latter often has heavier soil and more conspicuous tussock grasses.

Land systems

Recorded in many systems in the survey, it is characteristic of sheet flood plains and is most common in Jundee, Monk, Tindalarra, Woodline and Yanganoo.

34. Creek bank woodland or shrubland (CBKW)

Sampling 7 inventory sites

General information

CBKW was described in both the Murchison River catchment (*Creekline Shrubland* vegetation type Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) rangeland surveys. It is an infrequent habitat consequent of the domination of sheet flood plains draining into salt lake systems. There are however stretches of the Warne and Greenough Rivers and numerous ephemeral creeklines incised into the extensive hardpan plains. Creek beds are characteristically between 20 and 50 m wide and up to 4 m deep, incised into hardpan, often with lenses of calcrete exposed. CBKW occurs throughout the survey area, all but the most substantial creeklines and rivers dispersing on reaching the nearly flat hardpan plains. It differs most from its north-eastern Goldfields counterpart in being less frequently dominated by eucalypts.

Physiognomy and composition of vegetation

The vegetation fringing creeklines often consists of a moderately close to close (25-50% projected foliar cover) woodland or tall shrubland with variably developed mid and low shrub strata and occasional perennial grasses. Seventy-one species were recorded at the seven inventory sites at an average of 18 species per site, two more than the survey average. All common species occur in other habitats; CBKW is distinctive in its geomorphology and the density and structural complexity of its vegetation compared to adjacent habitats. Where occasionally dominated by *Eucalyptus camaldulensis* (river red gum) in the north-east of the survey area, it is usually recognisable from quite some distance standing out from acacia or chenopod scattered shrubland.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – no single species common. Common – *Acacia aneura, Eremophila longifolia, Pittosporum phylliraeoides.*
Tall shrubs:	Dominant – most commonly *Acacia acuminata* subsp. *burkittii.* Common – *A. acuminata* subsp. *burkittii, A. aneura, A. ramulosa, A. tetragonophylla, Eremophila alternifolia, E. longifolia.*
Mid shrubs:	Dominant – very variable. Common – *Senna artemisioides* subsp. *filifolia, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – very variable. Common – *Senna artemisioides* subsp. *filifolia, Ptilotus obovatus, Scaevola spinescens, Solanum lasiophyllum.*
Perennial grasses:	None common.

Mistletoes *(Amyema* spp.) and sedges *(Juncus* spp.) are occasionally encountered.

Patterns of grazing impact

Such is the variability in understorey that it is difficult to assess grazing impacts. Certainly, one might expect to see a decline in palatable perennial shrubs in overgrazed situations, however their inconspicuousness may be quite natural. Accelerated creek bank erosion did not appear to be a major problem.

Nature conservation

CBKW is important for native fauna. It occurs both in eucalypt and acacia-dominated forms on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.).

Gradational associations

CBKW is a distinctive habitat that contrasts strongly with adjacent, sparser habitats.

Land systems

Mainly Tindalarra and Wilson.

35. Hardpan plain mulga grove (GRMU)

Sampling 10 inventory sites

General information

GRMU is characteristic of gently inclined sheet flood plains from the Pilbara to the north-eastern Goldfields (Payne and Mitchell 1993, Pringle 1994a). Groves are generally contour-aligned arcuate bands of denser vegetation separated by comparably impoverished run-off areas (Mabbutt and Fanning 1987). The groves have much deeper soil to hardpan and an abundance of tall shrubs with a morphology well suited to funnelling intercepted rain into the ground. This enhances soil moisture content in these fertile patches. The soils are usually red earths, occasionally light clays. It is likely that a combination of shade, well developed cryptogamic crusts and leaf litter enhances retention of soil moisture by insulating against evaporation. Thus, areas not only receive and hold a disproportionate amount of resources, they use them longer into dry periods than the comparatively harsh intergrove phases.

Mulga groving is most common in the north of the survey area, however it is not nearly as well developed as in the Ashburton and upper Fortescue River catchments (Payne *et al.* 1988, Payne and Mitchell 1993) where groves can extend to 40 m wide and 4 km long, along the contour. In this survey they are rarely 20 wide and 100 m long. The most impressive groves have *Acacia pruinocarpa* trees to over 10 m tall.

Physiognomy and composition of vegetation

Mulga groves are often moderately close to closed (>25% projected foliar cover, occasionally approaching 100%) tall shrubland; less frequently, low woodlands. The understorey is characteristically variable, reflecting the level of competition for ecological space from the upper storey. Perennial grasses are not usually a substantial component.

Seventy-five species were recorded at the 10 inventory sites, at an average of 17 species per site, one more than the survey average. Common species are also common elsewhere. The distinctive features are the processes which develop the groved patterns to maximise resource use in comparatively small resource rich patches (e.g. Tongway and Ludwig 1990). Biological productivity of a given arid area is thought to increase with increasing heterogeneity on the basis that limited resources are more efficiently used in fertile patches rather than if spread more evenly (Noy-Meir 1980).

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Acacia aneura*, occasionally *A. pruinocarpa* in the north-east. Common – no other common species.
Tall shrubs:	Dominant – *A. aneura.* Common – *A. craspedocarpa, A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable when present. Common – *Eremophila clarkei, E. forrestii, E. latrobei* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – very variable; stratum generally recognisable. Common – *E. clarkei, E. forrestii, E. latrobei* (KD), *E. metallicorum, Maireana convexa* (KD), *M. planifolia X. villosa, Ptilotus obovatus, R. eremaea, Sida calyxhymenia, Solanum lasiophyllum, Spartothamnella teucriiflora* (KD).
Perennial grasses:	Dominant – stratum rarely developed. Common – *Monachather paradoxa* (often as a facultative biennial), *Stipa elegantissima.*
Other common plant forms:	*Cheilanthes austrotenuifolia* (fern), *Dianella revoluta* (lily), *Marsdenia australis* (climber).

Patterns of grazing impact

Palatable understorey shrub species such as *Eremophila latrobei* and *Maireana convexa* may be removed under sustained heavy grazing pressure. In particularly degraded areas, groves develop rills through them, lose their ability to entrap sheet wash and nutrients and may gradually decline as resources become more evenly spread. This type of ecosystem collapse is rarely encountered and would indicate exceptionally poor land management.

Nature conservation

GRMU appears to be an important habitat for both invertebrate and macropod native fauna. Small areas occur on Wanjarri Nature Reserve in the adjacent north-eastern Goldfields (Pringle *et al.* in prep.). *Spartothamnella puberula* (P2) was collected once in GRMU and recorded at another site.

Gradational associations

Most similar to acacia-dominated drainage systems, but is distinctive and clearly defined.

Land systems

Most common in Yanganoo.

36. ‘Lateritic’ hardpan plain mulga shrubland (LHMS)

Sampling 8 inventory sites

General information

LHMS is largely restricted to sheet flood plains receiving run-on from greenstone dominated landscapes. It occurs as nearly level plains, usually with a substantial mantle of fine ironstone gravel and shallow (< 60 cm deep) loamy or sandy soils, often on hardpan. It is characterised by its mantle and comparatively low vegetation cover for a sheet flood (hardpan) plain in this region. It is an Eremaean habitat; similar plains have much higher plant cover near the wheatbelt. It was first described in the north-eastern Goldfields (Pringle 1994a).

Physiognomy and composition of vegetation

LHMS is generally a very scattered to scattered (<15% projected foliar cover) tall shrubland with a sparse understorey and occasional trees. Perennial grasses are not conspicuous.

Fifty-one species were recorded at the eight inventory sites at an average of 13 per site, three species less than the survey average. All species common to LHMS are commonly encountered in other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Common – *Acacia aneura.*
Tall shrubs:	Dominant – variable; usually acacias; *A. aneura* most common. Common – *A. aneura, A. grasbyi, A. ramulosa, A. tetragonophylla* and *Eremophila fraseri.*
Mid shrubs:	Dominant – variable; acacias or eremophilas. Common – *A. ramulosa, A. tetragonophylla, Eremophila forrestii* (KD), *E. fraseri, E. latrobei* (KD), *Scaevola spinescens.*
Low shrubs:	Dominant – variable; *Ptilotus obovatus* most common. Common – *E. forrestii* (KD), E. *latrobei* (KD), *Maireana convexa* (KD), *P. obovatus* (KD), *P. schwartzii* (KD), *Scaevola spinescens, Sida calyxhymenia* (KD), *Solanum lasiophyllum and Spartothamnella teucriiflora* (KD).

Perennial grasses:	Dominant – stratum not usually present. Common – *Monachather paradoxa* (often a facultative biennial).
Other common plant forms:	*Dianella revoluta* (lily).

Patterns of grazing impact

Palatable understorey species such as *Eremophila latrobei*, *Maireana convexa* and *Ptilotus schwartzii* are likely to decline under excessive grazing pressure, possibly from open, exposed areas first and then from under tall shrub canopies (Hacker 1979). Such decreases do not appear to trigger an increase in unpalatable species as occurs in some other similar habitats with sandier soils. Soils are mostly stable reflecting the protection of ironstone gravel mantles and diffuse sheet flooding on nearly level, broad slopes. These hydrological characteristics however make LHMS susceptible to water starvation and consequent shrub deaths downslope of impedances to natural sheet flows.

Nature conservation

Appears not to have particularly high conservation value.

Gradational associations

A distinctive sheet flood plain habitat that often grades upslope into *Stony ironstone mulga shrubland* (SIMS) and laterally into *Hardpan plain mulga shrubland* (HPMS).

Land systems

Most extensive in Jundee; also Rainbow and Violet.

37. Hardpan plain mulga and bowgada shrubland or woodland (MUBW)

Sampling 26 inventory and 58 condition sites

General information

MUBW is described for the first time in this report; it was treated as part of *Hardpan Mulga Shrubland* in the Murchison River catchment (Curry *et al.* 1994). It occurs on slightly deeper and sometimes lighter loams than *Hardpan plain mulga shrubland* (HPMS) and receives more concentrated run-on. As a result, clumping of vegetation is generally less pronounced than in several similar habitats, indicative of the capacity of these sheet flood plains to

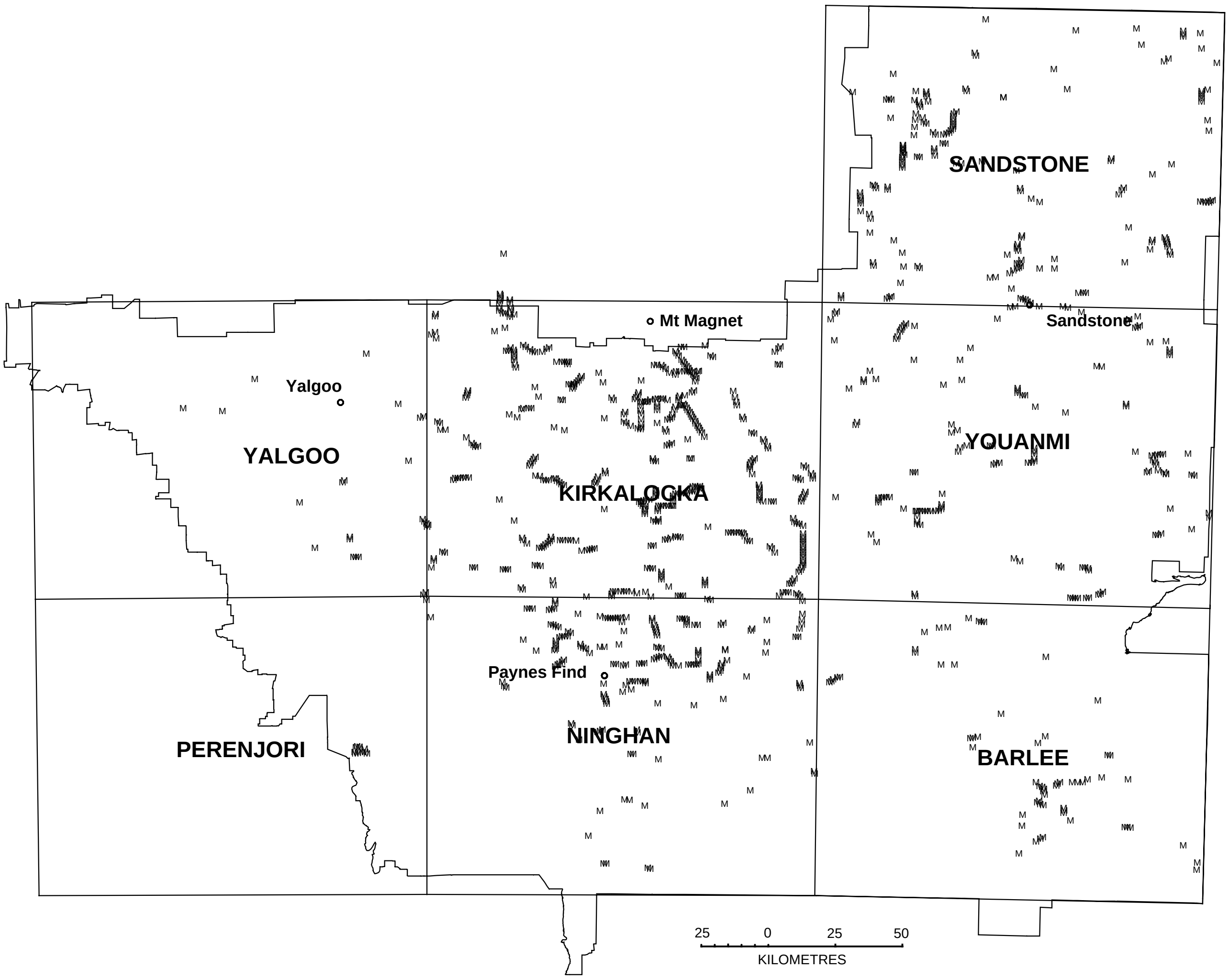

Figure 6. The distribution of traverse recordings of MUBW (M) habitat in the survey area

support a substantial cover of vegetation without major resource partitioning.

It is very common on hardpan plains throughout most of the survey, occurring less frequently in the far south and west of the survey area (Figure 6). As with most habitats in this group, MUBW is subject to sheet flooding after rain and is susceptible to water starvation and subsequent shrub deaths downslope of impedances to sheet flow.

Physiognomy and composition of vegetation

MUBW generally consists of scattered to moderately close (15-30% projected foliar cover) tall shrubland, but is occasionally dominated by mid shrub or tree strata. Low shrub strata are also usually present and perennial grasses, while usually present, are usually a minor component of the vegetation. One hundred and thirteen species were recorded at the 26 inventory sites, at the survey average of 16. All common species are also common in other habitats.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – *Acacia aneura.* Common – no other common species.
Tall shrubs:	Dominant – *Acacia ramulosa* or *A. aneura.* Common – *A. acuminata* subsp. *burkittii, A. tetragonophylla.*
Mid shrubs:	Dominant – variable; most commonly *A. ramulosa.* Common – *A. aneura, A. ramulosa, Eremophila eriocalyx* (KD), *E. forrestii, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – variable; most commonly *Eremophila forrestii* or *Ptilotus obovatus.* Common – *E. forrestii, Maireana convexa* (KD), *Ptilotus obovatus* (KD) and *Rhagodia eremaea.*
Perennial grasses:	Dominant – *Monachather paradoxa* (often as a facultative biennial). Common – *Stipa elegantissima.*
Other common plant forms:	*Dianella revoluta* (lily).

Patterns of grazing impact

Grazing impacts are a relatively minor influence on the structure and floristic composition of this vegetation compared with chenopod shrubland. This is largely due to the preponderance of (unpalatable) species whose density is not affected by grazing pressure.

While decreasers make up 42% of species present on average at condition sites, they comprise only 23% of shrubs counted. Decreasers support considerably less biomass per plant than dominant species such as *Acacia ramulosa* (bowgada). While biomass was not assessed, palatable perennial shrub biomass may represent less than a tenth of total perennial shrub biomass in MUBW habitat types.

Soils are not susceptible to erosion, reflecting negligible slope and protection from wind afforded by substantial shrub cover.

Spatial patterns in site attributes in relation to a distance from water were highly significant, but very weak. In other words, the attributes showed definite differences with increasing distance from water, but the differences were, on average, very small.

Cryptogamic crusting of the soil, total shrub cover, the number of decreaser species and their density (and their proportional representation of all species and densities) increased slightly (all R values $< .15$, but p values < 0.01) away from water. Conversely, increaser species numbers and densities declined away from water, similarly significantly but weakly. The increasers showed no significant trend as proportions of total numbers of species and density, indicating that they are a minor part of the vegetation in this habitat.

The decreaser species found to be significantly ($p < .05$) correlated with distance from water were:

Eremophila compacta
Eremophila forrestii
Maireana villosa
Ptilotus obovatus
Ptilotus schwartzii
Rhagodia eremaea

The weakness of the patterns in relation to distance from water may not reflect the real severity of grazing impacts. Only two condition sites were further than four kilometres from the nearest watering point and none was further than 4.5 km. This reflects the ease of obtaining good quality groundwater and the highly (pastorally) developed nature of landscapes in which MUBW is found. A combination of fresh drinking water and abundant shade would encourage stock to spread out from watering points to graze, limiting the amount of variation in historical grazing pressure across these well-developed paddocks.

Unfortunately, no true benchmark sites (perhaps greater than seven or eight kilometres from the nearest watering points) were sampled and hence the weak patterns of impact cannot be put into the context of what MUBW is like in an undeveloped or 'pristine' condition. Landsberg *et al.* (1997) have shown marked differences in plant and animal diversity in analogous eastern Australian habitats between distances such as those sampled for MUBW and benchmark sites.

The highly significant nature of the weak spatial patterns described above would suggest that these eastern Australian findings probably apply to MUBW and similar low woodland/tall shrubland habitats in Western Australia. This is certainly the case in the Murchison River catchment, immediately to the north of this survey area (Curry *et al.* 1994).

Gradational associations

In sandier areas subject to less run-on, MUBW grades into sclerophyll sandplain habitats as *A. aneura* becomes less conspicuous and perennial grasses increase in density with *A. ramulosa* (e.g. *Sandplain grassy bowgada shrubland* – SWGS).

Land systems

Numerous; most extensive in Tealtoo, Woodline and Yowie.

38. Wanderrie bank grassy mulga shrubland (WABS)

Sampling 5 inventory sites

General information

WABS has previously been described in both the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) surveys. It occurs as low (<50 cm) sandy banks in the lower sectors of sheet flood plains. Soils are generally sandier and deeper than on adjacent sheet flood (hardpan) plains and even where not readily recognisable as banks, their sandy surfaces and understorey vegetation usually indicate a change in habitat. Wanderrie grasses such as *Monachather paradoxa* and shrubs such as *Eremophila forrestii* are often more prominent on WABS.

Sandy soil surfaces enhance infiltration of sheet flow (with nutrients) and retard the evaporation driven capillary rise of soil moisture, conferring a better soil moisture status than adjacent plains. WABS is an Eremaean habitat and was not observed in the far south and west of the survey area.

Physiognomy and composition of vegetation

WABS generally occurs as a scattered to moderately close (15-25% projected foliar cover) tall shrubland with a well developed low shrub stratum and characteristically variable mid shrub and perennial grass strata. Perennial grasses rarely attain a basal area of 5%. Forty-eight species were recorded at the five WABS sites at the survey average of 16 species per site. All species were recorded elsewhere.

The following species (by strata) are dominant and/or common:

Trees:	Not recorded.
Tall shrubs:	Dominant – *Acacia aneura* or *A. ramulosa.* Common – *A. acuminata* subsp. *burkittii, A. grasbyi, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable. Common – *A. ramulosa, A. tetragonophylla, Senna artemisioides* subsp. *filifolia, Eremophila forrestii, Rhagodia eremaea.*
Low shrubs:	Dominant – *Eremophila forrestii* or *Ptilotus obovatus.* Common – *S. artemisioides* subsp. *filifolia, Maireana planifolia X villosa, R. eremaea, Sida* aff. *virgata, Solanum lasiophyllum, S. orbiculatum.*
Perennial grasses:	Dominant – *Monachather paradoxa.* Common – *Eragrostis eriopoda.*

Patterns of grazing impact

Palatable perennial shrubs and grasses can be removed under excessive grazing pressure. Gardiner (1984, 1986a,b) found that kangaroo grazing suppressed recruitment in *Eragrostis eriopoda* with a concomitant increase in *Eremophila spectabilis* compared with kangaroo exclosure. Hacker (1986) reported sealing of the soil surface and subsequent decline in the ability of water to infiltrate the profile.

Nature conservation

The flora is not particularly distinctive, consisting largely of common species. However, the mosaic of sandy topsoil layers may provide opportunities for burrowing animals not usually present in sheet flood plains. WABS occurs on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.).

Gradational associations

Poorly developed sandy banks often resemble adjacent sheet flood plain habitats. Conversely, exceptionally well developed sandy banks may support *Triodia basedowii* hummocks and resemble true sandplain communities.

Land systems

Marlow, Melaleuca and Monk.

Other minor habitats associated with the 'broad sheet flood hardpan plain sclerophyll shrubland or woodland habitats'

Creekline bottlebrush shrubland (CBBS) – 4 inventory sites

This distinctive but minor habitat occurs as close (>30% foliar cover) tall shrubland dominated by *Callistemon phoeniceus* (river bottlebrush) fringing creeklines and ephemeral pools. Other common species found with *C. phoeniceus* include *Acacia acuminata* subsp. *burkittii, A. tetragonophylla, Ptilotus obovatus* and *Rhagodia eremaea. Juncus aridicola* (sedge) may also be common in the understorey. This habitat is particularly aesthetically pleasing when the deep red bottlebrush flowers are in full bloom. Water birds such as the black-tailed native hen or 'Murchison chook' (*Gallinula ventralis*) breed in good seasons when pools hold water.

H. PLAINS TRANSITIONAL TO SANDPLAIN WITH SCLEROPHYLL SHRUBLAND OR WOODLAND HABITATS

This group typically occurs on near level plains with deep (>60 cm) light textured loam or sandy soils which are subject to considerably more diffuse run-on than the hardpan plain habitats described above as group (G). The first two habitats have southern affinities and are dominated by *Eucalyptus loxophleba* (York gum) and *Callitris glaucophylla* (native

pine). *E. loxophleba* occurs in slightly more alluvial areas and *C. glaucophylla* favours sandier areas.

The second two are typically Eremaean and dominated by *Acacia aneura* and arid zone allies such as *Eremophila forrestii* and *Eragrostis eriopoda*. These are very similar, differing principally in the relative dominance of upper storey (PLMS) to perennial 'wanderrie' grass layer (MUWA). The causal factors determining their respective distributions are difficult to evaluate. As one moves south into better and more reliable winter rainfall the shrub stratum predominates, but also occurs in northern areas. The answer probably lies in the interaction between reliability of growth season and patterns of local surface water redistribution that variably affects shrubs' ability to compete with the drought tolerant wanderrie grasses, *E. eriopoda* in particular.

<u>Callitris</u> <u>glaucophylla</u> *(native pine) is common on deep sandy soil habitats (in this case PINW) transitional to sandplains and receiving diffuse run-on. This habitat group is particularly common in the south of the survey area in Yowie and Bannar land systems. Generally well developed shrub strata provide protection from soil erosion.*

39. Plain York gum acacia woodland (PYAW)

Sampling 40 inventory sites

General information

PYAW is very similar to *Calcareous plain eucalypt mallee/acacia woodlands/shrubland* (CEAS) described in the north-eastern Goldfields survey (Pringle 1994a). The major differences include the infrequent, rather than normal presence of calcrete in soil and its dominance by *Eucalyptus loxophleba* rather than *E. concinna, E. oleosa* and *E. trichopoda.* PYAW occurs on deep (>60 cm) red earths, sometimes over hardpan.

'Eucospheres' (particular suites of species found growing under eucalypt canopies among leaf litter) are common in PYAW and are characterised by low and mid shrubs rather than the acacias and other taller shrubs that predominate between eucalypts. It is common in the southern half of the survey area.

Physiognomy and composition of vegetation

PYAW is commonly a scattered to moderately close (15-30% projected foliar cover) low woodland or tall shrubland (where eucalypts are sparser than acacias). Low shrub strata are also well developed, with variably developed mid shrub strata and occasional, poorly developed perennial grass strata.

One hundred and eighty-nine species were recorded at the 40 inventory sites at an average of 23 per site, considerably higher than the survey average of 16. This species richness may, at least in part, reflect internal heterogeneity associated with 'eucospheres' and this habitat's blend of South-West and Eremaean Botanical Province floras. PYAW is the most species rich of the major habitats described in this report. It also contained 14 species not encountered in other habitats and a further 14 species encountered in only one other habitat. These make up 15% of all PYAW species and indicate a particularly high floristic uniqueness in this survey area. Many of these species (22) were recorded only once, however PYAW is unusual in having a few multiple records of unique or nearly unique species indicative of its flora. These include *Eremophila pachyphylla* (5 records), *Eucalyptus* aff. *corrugata* (3), *E. transcontinentalis* (3) and *Maireana* aff. *georgei* (3).

The following species (by strata) are dominant and/or common:

Trees:	Dominant – various eucalypts; most commonly *E. loxophleba.* Common – *E. loxophleba.*
Tall shrubs:	Dominant – variable; commonly acacias. Common – *Acacia acuminata* subsp. *burkittii, A. ramulosa, A. tetragonophylla* and *Exocarpos aphyllus.*
Mid shrubs:	Dominant – very variable; S*enna artemisioides* subsp. *filifolia* most frequently (13 sites). Common – *Acacia colletioides, A. tetragonophylla, S. artemisioides* subsp. *filifolia* (KI), *Eremophila decipiens, Olearia pimeleoides, Rhagodia eremaea, Scaevola spinescens.*
Low shrubs:	Dominant – variable; *Ptilotus obovatus* most commonly (16 sites). Common – *Senna artemisioides* subsp. *filifolia* (KI), *Enchylaena tomentosa* (KD), *Eremophila decipiens, Maireana georgei* (KD), *M. thesioides* (KD), *Olearia muelleri, Ptilotus obovatus, Rhagodia drummondii, R. eremaea, Scaevola spinescens, Solanum orbiculatum* (KI).
Perennial grasses:	Dominant – very variable when recorded (21 sites). Common – *Amphipogon caricinus, Monachather paradoxa* (often a facultative biennial), *Stipa elegantissima.*

Patterns of grazing impact

Grazing can reduce the mix and abundance of palatable perennial low shrubs. These include *Enchylaena tomentosa*, *Maireana georgei* and *M. thesioides*. It is likely this decline will allow some increase in unpalatable species, including *Senna artemisioides* subsp. *filifolia* and *Solanum orbiculatum.* A large proportion of inaccessible and unpalatable foliage in this habitat bestows some resilience to overgrazing. Soil erosion does not appear to be a major problem.

Nature conservation

This regionally significant habitat occurs on Mt Elvire pastoral lease, which was acquired by the Department of Conservation and Land Management in May 1991. Its structural diversity of fauna habitats including those for invertebrates among the accumulated leaf litter beneath clumps or singular eucalypts, may bestow significant conservation value.

Gradational associations

Chenopods may become more conspicuous between eucalypt clumps on better developed, heavier textured soils (PYCW) and, conversely the acacia component may become dominant, perhaps with *Callitris glaucophylla* on deeper, coarser textured soil receiving less run-on.

Land systems

Most common in Doney, Euchre, Pindar and Yowie.

40. Plain native pine acacia woodland or shrubland (PINW)

Sampling 14 inventory sites

General information

PINW occurs on deep sandy soils in the southern third of the survey area and is named after *Callitris glaucophylla* (native pine). The nearly level plains are usually subject to diffuse sheet flow, occupying areas slightly higher than those associated with *Acacia aneura* or *Eucalyptus loxophleba* dominated communities. *Callitris* species are typically sensitive to fire, however a substantial acacia shrub component, not particularly flammable in nature, affords some protection by reducing the potential for the build up of annual grass fuel in good summer seasons.

Physiognomy and composition of vegetation

PINW generally occurs as a moderately close (20-30% projected foliar cover) low woodland or tall shrubland, reflecting the dominance of *C. glaucophylla* and acacias respectively. Mid and low shrub and perennial grass strata are generally present but subordinate.

One hundred-and-two species were recorded at the 14 sites, at an average of 20 per site, 4 higher than the survey average. Species common to PINW are also common in at least several other habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – *Callitris glaucophylla*. Common – *Acacia aneura.*
Tall shrubs:	Dominant – variable; usually acacias. Common – *Acacia acuminata* subsp. *burkittii, A. aneura, A. ramulosa, A. tetragonophylla* and *Hakea recurva.*
Mid shrubs:	Dominant – very variable. Common – *Acacia colletoides, Alyxia buxifolia, Senna artemisioides* subsp. *filifolia* and *Rhagodia eremaea.*
Low shrubs:	Dominant – variable. Common – *S. artemisioides* subsp. *filifolia, Enchylaena tomentosa* (KD), *Minuria leptophylla, Olearia pimeleoides, Ptilotus obovatus, Rhagodia eremaea.*
Perennial grasses:	Dominant – variable; most commonly *Amphipogon carcinus/strictus.* Common – *Amphipogon caricinus/strictus, Monachather paradoxa* (often as a facultative biennial), *Stipa elegantissima.*
Other common plant forms:	*Dianella revoluta* (lily).

Patterns of grazing impact

PINW has few palatable perennial shrubs and is generally not preferred for stock, although they may be attracted to abundant herbage and perennial grasses in good summer seasons. Signs of grazing impact are not obvious in PINW as a result of the overwhelming presence of largely unpalatable shrubs and the predominance of mostly inaccessible foliage on tall shrubs and trees. *Enchylaena tomentosa* and a various small *Maireana* spp. may decline under excessive grazing pressure, but are rarely conspicuous in ungrazed areas. Substantial (unpalatable) shrub cover and diffuse run-on preclude accelerated soil erosion from being a problem.

Nature conservation

It is one of the habitats least threatened by livestock grazing. It is not known to occur in conserved lands.

Gradational associations

PINW grades into *Plain sandy loam mulga shrubland* (PLMS) and other sandy habitats where *Callitris glaucophylla* is absent.

Land systems

Mainly Bannar, Kalli and Yowie.

41. Plain sandy loam mulga shrubland (PLMS)

Sampling 12 inventory sites and 2 condition sites

General information

PLMS is described here for the first time. It was included in MUWA in the north-eastern Goldfields rangeland survey but has better developed shrub strata and a poorer developed perennial ‘wanderrie’ grass stratum. It occurs on nearly level plains subject to diffuse run-on and has generally deep (>60 cm) sandy loam soils over hardpan. PLMS was encountered on all map sheets, although most frequently recorded from near Paynes Find north-eastwards. PLMS was the third most frequently recorded habitat (496 times) in the traverse record.

Physiognomy and composition of vegetation

PLMS usually occurs as scattered to moderately close (15-30% projected foliar cover) tall shrubland, although the tree, mid shrub and low shrub strata may occasionally attain dominant or co-dominant status and are usually well developed strata. Perennial grass strata are less frequent and less well developed.

Sixty-nine species were recorded at the 12 inventory sites, at an average of 14 species per site, two less than the survey average. Species common to PLMS are also common to a number of other habitats.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – *Acacia aneura.* Common – no others.
Tall shrubs:	Dominant – *A. aneura.* Common – *A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – *A. ramulosa* or *Eremophila forrestii.* Common – *A. tetragonophylla, E. latrobei* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – *E. forrestii.* Common – *E. latrobei* (KD), *Maireana convexa* (KD) *Solanum lasiophyllum* and *Spartothamnella teucriiflora.*
Perennial grasses:	Dominant – *Monachather paradoxa* (often a facultative biennial). Common – *Eragrostis eriopoda.*

Patterns of grazing impact

Sensitive decreasers including *Eremophila latrobei* and *Maireana convexa*, are likely to be the first to decline under sustained heavy grazing pressure (Fletcher 1991). More resilient species such as *Spartothamnella teucriiflora* are next likely to decline and finally resilient and less attractive species, *Eremophila forrestii* in particular. While *E. forrestii* is not particularly attractive to stock in this sandy habitat, fenceline differences prove it is palatable and can be removed from sandy habitats by excessive grazing. Soil erosion is not usually a problem, however surface sealing may occur in particularly severely degraded areas (Hacker 1986).

Nature conservation

PLMS is not a preferred grazing habitat; it contains species common to large areas of other habitats and is not known to support species of particularly high conservation value. It is a minor habitat on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.).

Gradational associations

PLMS grades into *Hardpan plain mulga shrubland* (HPMS) as run-on increases and soils become slightly heavier (clay loams) and shallower. It is floristically very similar to *Mulga wanderrie grassland or shrubland* (MUWA).

Land systems

Most common in Monk, Woodline, Yanganoo and Yowie.

42. Mulga wanderrie grassland or shrubland (MUWA)

Sampling 4 inventory sites

General information

MUWA was previously described in the north-eastern Goldfields survey (Pringle 1994a). It usually occurs on very low interfluves in extensive sheet flood plains and areas of diffuse run-on in sandplains. Soils are generally deep (>60 cm) sandy loams or loamy sands, sometimes on hardpan. It is an Eremaean habitat confined to the north-east of the survey.

Long-standing dead mulga are characteristic; regeneration appears to be sporadic and may have been partly suppressed by a well developed perennial grass stratum. The commonly dominant grass *Eragrostis eriopoda* is very well adapted to this harsh infertile habitat, being tolerant to prolonged dry spells and grazing by a variety of herbivores.

Physiognomy and composition of vegetation

MUWA ranges from isolated tall shrubs and trees to scattered tall shrubland (to 20% projected flora cover) reflecting differences in mulga deaths and regeneration. Structural dominance is variable, with well developed shrub strata and a prominent wanderrie grass component. Tall shrubs or grasses are commonly dominant.

A total of 42 species were recorded at the four inventory sites, at the survey average of 16 . MUWA’s flora is common in other habitats.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally *Acacia aneura.* Common – none.
Tall shrubs:	Dominant – *A. aneura.* Common – *A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – *Eremophila forrestii.* Common – *Senna glutinosa* subsp. *charlesiana, Rhagodia eremaea.*
Low shrubs:	Dominant – *E. forrestii.* Common – *Senna artemisioides* subsp. *filifolia, Maireana convexa* (KD),

Ptilotus obovatus, R. eremaea, Solanum lasiophyllum.

Perennial grasses: Dominant – *Eragrostis eriopoda* or *Monachather paradoxa.*

Patterns of grazing impact

MUWA is affected by grazing in several inter-related ways. Palatable shrubs (e.g. *Maireana convexa*) and grasses (e.g. *Monachather paradoxa*) may be removed or reduced in density. This may allow an increase in unpalatable shrubs (e.g. *Eremophila spectabilis*) or, less frequently grasses (e.g. *Eriachne helmsii*, Gardiner 1984, 1986a,b, Hacker 1979, 1984a,b). In particular severe cases of degradation of naturally sandy soil surfaces may become sealed, effectively reducing infiltration and soil moisture (Hacker 1986). While the surface remains healthy, it would appear from destocked areas that perennial grasses re-establish readily. Increaser shrubs appear to persist and decreasers not to re-establish as quickly.

Nature conservation

MUWA is represented on Wanjarri Nature Reserve and Goongarrie National Park to the east of this survey area. Its mix of perennial grasses and shrubs may provide a more varied range of habitat for a variety of fauna than more widespread mulga habitat types.

Gradational associations

MUWA grades into *Hardpan plain mulga shrubland* (HPMS) towards adjacent areas slightly downslope and receiving more concentrated run-on where perennial grasses decline and tall shrub cover becomes more evenly distributed and dominant.

Land systems

Kalli, Monk, Tindalarra, Tyrrell, Woodline, Yanganoo and Yowie.

I. SANDPLAIN HUMMOCK GRASSLAND HABITATS

Spinifex grasses dominate sandplains in the arid zone of Western Australia (Beard 1991). In this survey area they occur almost exclusively on the three eastern map sheets, although small areas of spinifex sandplain extend to the Yalgoo map sheet in the north-west. As a rule, the far western

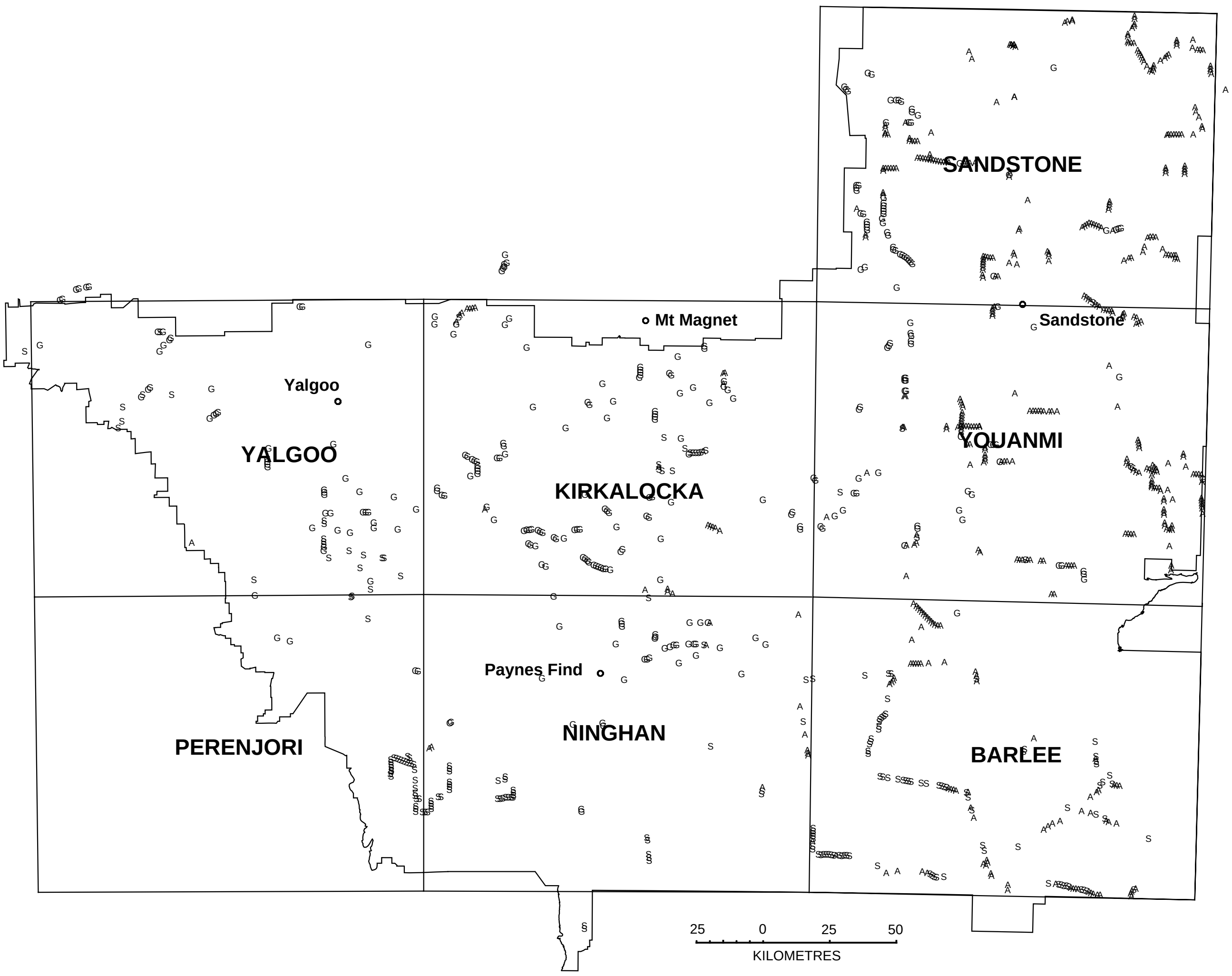

Figure 7. The distribution of different vegetation on sandplains in the survey area; SASP (A), SWGS (G), SCMS (S).

and southern parts of the survey area's sandplains are dominated by mixes of myrtaceous shrubs and larger acacias, mallees, melaleucas and proteaceae (Figure 7). Where spinifex and shrub-dominated plant associations occur together in the south-east, it appears that soil type is a primary influence on distribution, with spinifex on flatter, aeolian red sand and shrubs predominant on undulating more yellow, 'lateritic' sandplain.

This survey area supports the south-western limit of spinifex-dominated sandplains, a uniquely Australian arid zone habitat type. Fire is an important influence on ecosystem dynamics including nutrient releases which support floristically rich successions which usually trend back to spinifex hummock grasslands. A variety of small, ground dwelling lizards and mammals avail themselves of the protection provided by prickly hummocks.

Two major habitats are discussed below. The first includes a variety of subordinate shrub and mallee associations on generally extensive red sand plains. The second is associated with diffuse run-off from adjacent outcrops, often occurring on the periphery of the first, or as patches around outcrops scattered through it.

43. Sandplain spinifex hummock grassland (SASP)

Sampling 19 inventory sites

General information

SASP or analogous habitats have been described in the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) rangeland surveys. It dominates the arid interior of Western Australia beyond the pastoral zone (Beard 1991). Its management for nature conservation purposes and the impact of traditional Aboriginal land management and then dislocation by European urbanisation influences have been the subject of much discussion and controversy (Recher and Christenson 1981, Adamson and Fox 1982, Hallam 1985, Pearson 1991). Major points of contention include whether Aboriginal people extensively and regularly patch burned spinifex, whether this pattern of management increases habitat richness and biological diversity, whether urbanisation to remote towns and settlements has resulted in less frequent, more intense and extensive wildfires and how all these factors relate to current nature conservation. The reality may be some truth and relevance on both sides of debate on these points of contention.

Pastoralists in the Sandstone Land Conservation District and surrounds burn spinifex to promote a few years of improved pasture from annuals and facultative biennials (Williams and Tauss 1990, Tauss 1991). They prefer patch burning to prevent losing the use of paddocks after a big fire until it is ready to carry fire again. The impacts of this fire regime and grazing on biological diversity are not known. It certainly increases habitat diversity, but the quality of those habitats may be affected by grazing.

Physiognomy and composition of vegetation

Shrub cover varies greatly from less than 5% to over 25% projected foliar cover. High shrub cover is particularly associated with past fire successions involving acacias, particularly *A. coolgardiensis*, or heath species such as *Baekea cryptandroides*.

Spinifex cover increases with time after fire, reaches maturity and then may decline as hummocks senesce. Mature spinifex populations attained a ground cover of up to 40%, which is consistent with the findings of Winkworth (1967) in central Australia.

One hundred and forty-two perennial species were recorded at the 19 inventory sites, at an average of 14 species per site; two less than the average site species richness. The high total number of species and low average species richness indicate tremendous floristic diversity between sites. Accordingly, sub-habitats were distinguished on the basis of the floristics of the most prominent stratum subordinate to the hummock grass stratum in the north-eastern Goldfields (Pringle 1994a). They are:

SAGS – *Eucalyptus gongylocarpa* (marble gum) scattered trees.

SAHS – Heath e.g. *Baekea cryptandroides* and *Wehlia thryptomenoides.*

SAWS – Wattles e.g. *Acacia coolgardiensis.*

SAMA – Mallees e.g. *E. kingsmillii.*

SAMU – Mulga (*Acacia aneura*): this has been treated as a distinct habitat, see below.

Sand dune shrubland (SDSH) was also considered part of SASP (Pringle 1994a) but is discussed briefly in its own right in the final group in this chapter.

Grevillea and *Hakea* spp. may also dominate a subordinate mid or tall shrub stratum.

Considering these sub-habitats together (except where already indicated), the following species (by stratum) are dominant or common in SASP (numbers in parentheses indicate the number of sites at which that species dominated that stratum):

Trees:	Dominant – *Acacia aneura* (1), *Eucalyptus gongylocarpa* (3). Common – *Acacia aneura.*
Mallees:	Dominant – *Eucalyptus brachycorys* (1), *E.* aff. *cylindroidea* (1), *E. kingsmillii* (1), *E. melanoxylon* (1), *E.* aff. *oleosa* (1). Common – no mallee species common,

	E. kingsmillii was most frequent (4 sites).
Tall shrubs:	Dominant – *Acacia acuminata* subsp. *burkittii* (1), *A. aneura* (1), *A. coolgardiensis* (5), *A. ramulosa* (1). Common – *A. aneura, A. coolgardiensis.*
Mid shrubs:	Dominant – *Acacia colletioides* (1), *A. coolgardiensis* (4), *A. ramulosa* (1), *Senna artemisioides* subsp. *filifolia* (1), *Eremophila pachyphylla (1), Grevillea didmybotrya* (1), *Melaleuca uncinata* (1), *Phebalium canaliculatum* (2). Common – *A. coolgardiensis.*
Low shrubs:	Dominant – *Senna artemisioides* subsp. *filifolia* (1), *Daviesia benthamii* (1), *Eremophila clarkei* (1), *E. forrestii* (1), *Eutaxia* sp. (1), *Grevillea didmybotrya* (1), G. *obliquistigma* (1), *Micromyrtus flaviflora* (1), *Phebalium canaliculatum* (1), *Westringia* sp. (1). Common – *Ptilotus obovatus.*
Perennial grasses:	Dominant – *Amphipogon caricinus/strictus* (1), *Monachather paradoxa* (1), *Triodia longipalea* (1), *P. rigidissima* (4), *Triodia basedowii* (12). Common – *Amphipogon carcinus/strictus*, *Monachather paradoxa* (often a facultative biennial), *Triodia basedowii.*

Triodia rigidissima is commonly dominant in the south-east of the survey area, with *Triodia basedowii* more dominant around Sandstone and north and east.

Successions after fire often involve many species and characteristically vary considerably from place to place as a result of numerous factors, including time and rainfall since the burn, season and intensity of the burn and seasonal conditions at the time of the burn. Prominent after-fire grasses are *Aristida contorta*, *Monachather paradoxa* and *Amphipogon* spp. Among the common annual and biennial forbs are *Bonamia rosea*, *Dicrastylis* spp., *Goodenia mueckeana*, *Keraudrenia integrifolia*, *Leptosema chambersii, Rulingia loxophylla, Scaevola* spp. and *Solanum plicatile.*

Patterns of grazing impact

The grazing ecology of SASP is not well known and its low long-term pastoral productivity may preclude funding of this type of research. Deferring grazing for a season after fire may facilitate the establishment of seral species in competition with spinifex and delay its resumption of dominance, thus increasing the quality and duration of improved pasture. Soil erosion is not usually a prolonged problem as plant cover re-emerges soon after rains following a fire.

Nature conservation

SASP is habitat for a wide range of invertebrate and vertebrate fauna, many of whose lives revolve around spinifex as a food source (termites) or, more importantly, for shelter (small native reptiles and mammals). Rare flora are often found in sandplain (Pringle 1994b). *Epacridaceae* gen. sp. nov. for instance was collected among spinifex hummocks in the south-east corner of the survey area. SASP is extensive on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.) and undeveloped land on pastoral leases and east of the pastoral zone (Pringle 1995a).

Gradational associations

SASP grades into *Sandplain mulga spinifex hummock grassland* (SAMU) under the influence of diffuse run-on and slightly finer textured soil.

Land systems

Mainly Bullimore, Marmion and Tyrrell; also Bannar, Kalli, Pindar and Yowie.

44. Sandplain mulga spinifex hummock grassland (SAMU)

Sampling 5 inventory sites

General information

SAMU is similar to SASP in having a prominent hard spinifex grass stratum, but differs in landscape setting and by having a well developed *Acacia aneura* overstorey. It occurs on the distal parts of extensive sandplains and adjacent to rock outcrops in sandplains, in areas subject to diffuse run-on, often as a broad transitional zone between SASP and *A. aneura* sheet flood systems on hardpan plains (group G). It is most common on the periphery of extensive sandplains on the Youanmi and Sandstone 1:250,000 scale map sheets in the north-east of the survey area.

Physiognomy and composition of vegetation

SAMU occurs as scattered (10-20% projected foliar cover) tall shrubland over a hummock grass stratum of roughly equal cover; neither stratum is more frequently dominant and co-dominance is common (based on cover). Trees are common and understorey shrubs are generally subordinate to the overstorey and spinifex.

Thirty-six species were recorded at the 5 inventory sites at an average of 12 species per site, 4 below the survey average. SAMU's flora consists of species more commonly associated with mulga plains or open spinifex sandplain communities.

The following species (by stratum) are dominant and/or common:

Trees and mallees:	Dominant – *Acacia aneura* or *Eucalyptus kinsgmillii.* Common – no other trees (or mallees) are common.
Tall shrubs:	Dominant – *Acacia aneura.* Common – *A. coolgardiensis, A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – variable, usually acacias. Common – *A. colletioides, A.*

coolgardiensis, A. ramulosa, A. tetragonophylla, Eremophila clarkei, E. forrestii.

Low shrubs: Dominant – not normally present as a recognisable stratum.
Common – *E. forrestii, Solanum lasiophyllum.*

Perennial grasses: Dominant – *Triodia basedowii.*
Common – *Monachather paradoxa* (often a facultative biennial).

Patterns of grazing impact

Palatable low shrubs including low *Maireana* spp. and others associated with mulga plains habitats occur in various mixes in SAMU and may be removed by excessive grazing pressure. Soil erosion is not usually a problem due to the diffuse nature of run-on and the protection afforded against the wind by the predominantly ungrazed perennial vegetation. Most species have unpalatable foliage and hence grazing does not usually substantially alter this habitat.

Nature conservation

SAMU may be important to native mammals as a shelter in generally open spinifex plains. Anecdotal evidence from pastoralists indicates that it is important as shelter for stock. SAMU occurs on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep.).

Gradational associations

SAMU grades into *Sandplain spinifex hummock grassland* (SASP) as spinifex cover increases and *A. aneura* declines and other tall shrubs and mallees become dominant, but usually subordinate to spinifex as the influence of run-on diminishes and sand depth increases.

Land systems

Bullimore, Tyrrell and Yanganoo.

J. SANDPLAIN SCLEROPHYLL SHRUBLAND OR WOODLAND HABITATS

This group of habitats occurs throughout the survey area, but is better represented in the south and west, away from the typically Eremaean spinifex hummock grasslands. Better and more reliable winter rainfall is probably the critical factor in the transition from spinifex to shrub-dominated communities. Several of the habitats described below are typical of this transition from Beard's (1991) Eremaean Botanical Province to the South-West Botanical Province and South-Western Interzone. Keighery *et al*. (1995) also recognised a strong floristic and structural gradient from principally ericoid shrubs (mainly myrtaceae) to *Triodia* hummock grasslands in the south-east of this survey area. They also noted the floristic similarity between sandplain shrub flora and its ironstone range counterparts and their dissimilarity with more recent alluvial landscapes' flora.

Most of these habitats are not well regarded by pastoralists and have generally not been affected by pastoral management. Some small areas in the far west of the survey area have been 'parkland' cleared to improve pastures with introduced species and the application of fertilisers. The flora of these habitats may then be regarded as having little pastoral value and as being well conserved in its own right and as habitat for native fauna. Predation by introduced pests such as feral cats and foxes may have had an adverse impact on native fauna.

The sandplains in the south and west of the survey area contrast strongly with the open spinifex plains to the north-east. At times the assortment of acacias, melaleucas and grevilleas combines to form impenetrable thickets (SCMS habitat). While early explorers occasionally mistook this abundant above-ground biomass as indicating natural fertility, primary productivity is very low. This results from the poor water-holding capacity and low nutrient content of the sandy soils. Fire is an occasional, very intense disturbance in this group of habitats, releasing nutrients built up slowly over preceding decades.

45. Sandplain grassy bowgada shrubland (SWGS)

Sampling 8 inventory sites

General information

SWGS is most common south of the Murchison River catchment survey (Curry *et al.* 1994), where it was first described (*Sandplain Wanderrie Grassy Shrubland* vegetation type). It dominated large areas of sandplain in that area, being replaced by spinifex communities in the far east, a pattern continued south into this survey area and broadly indicated by the change from Bullimore and Tyrrell (spinifex) land systems in the east, to Kalli and Yowie westwards. It is principally an Eremaean habitat. SWGS generally occurs on deep (>60 cm) red sand; sometimes on the backslopes of substantial breakaway systems.

Physiognomy and composition of vegetation

Shrub cover is variable, most sites being a moderately close (20-30% projected foliar cover) tall shrubland with subordinate mid and low shrub and perennial grass components. Trees are occasionally prominent.

The perennial grass layer appears generally to be less well developed than in the Murchison River catchment, perhaps

reflecting the greater proportional effectiveness of winter rainfall southwards. Sixty-one species were recorded at the 8 inventory sites at the survey average of 16. Species common to SWGS are common to several other Eremaean sclerophyll habitats.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – rarely present. Common – *Acacia aneura.*
Tall shrubs:	Dominant – *Acacia ramulosa.* Common – *A. aneura, A. tetragonophylla, Callitris glaucophylla, Hakea recurva.*
Mid shrubs:	Dominant – variable; acacias or *Eremophila* spp. Common – *A. aneura, A. ramulosa, A. tetragonophylla, Eremophila forrestii, E. granitica* (KI), *E. latrobei* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – variable; *Eremophila forrestii* most commonly (4 sites). Common – *E. forrestii, E. georgei* (KI), *E. latrobei* (KD), *Maireana convexa* (KD), *M. villosa, R. eremaea, Sida* aff. *virgata.*
Perennial grasses:	Dominant – *Monachather paradoxa.* Common – *Amphipogon caricinus/strictus, Eragrostis eriopoda.*
Other common plant forms:	*Dianella revoluta* (lily).

Patterns of grazing impact

Curry *et al.* (1994) defined range condition classes primarily on the basis of perennial grass composition. That is not applicable in this survey area where *M. paradoxa* is the only commonly abundant perennial wanderrie grass. All the same, increasing grazing pressure is likely to reduce its prevalence. Where present, *Thyridolepis multiculmis* is likely to be even more sensitive to grazing pressure. Palatable shrubs including *Eremophila latrobei* and *Maireana convexa* are also likely to be removed under heavy grazing pressure. Unpalatable, invasive species are not widely characteristic of SWGS and soils are usually stable.

Nature conservation

SWGS is a common habitat not preferentially grazed by stock unless *A. ramulosa* is in seed (‘bowgada beans’). *Hemigenia brachyphylla* (P2) was recorded as the dominant low shrub at one site. This habitat suits mallee fowl for building their mounds.

Gradational associations

SWGS grades into *Sandplain acacia shrubland* (SACS) as the prominence of acacias associated with sandplain increases, often with a decline in wanderrie grasses and an increase in ericoid understorey shrubs.

Land systems

Mainly Kalli, Woodline and Yowie.

46. Sandplain acacia shrubland (SACS)

Sampling 26 inventory sites

General information

SACS occurs throughout the survey area on deep sands, which tend to be red in the north and east and buff in the west and south. It has previously been described in both the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle 1994a) rangeland surveys. It is not generally prone to fire, but when burnt may take decades to return to its former state (Curry 1986). It is common in the far west of the survey area, extending eastwards in a southerly arc through to the north-eastern Goldfields via the Perenjori, Ninghan and Barlee 1:250,000 scale map sheets.

Physiognomy and composition of vegetation

SACS generally occurs as a moderately close to close (20-50% projected foliar cover) tall shrubland. Mid and low shrubs are generally prominent as are occasional trees. Perennial grasses usually form a minor component. One hundred and thirty species were recorded at 26 inventory sites at an average of 13 species per site, 3 less than the survey average. The high species total for a relatively small number of sites and the low species richness per site reflects variability consistent with a habitat distributed across most of the biographical variation in this survey area. SACS includes species representative of sandplains in both the Eremaean (e.g. *Baeckea cryptandroides*) and South-West (e.g. *Baeckea* aff. *uncinella*) Botanical Provinces of Beard (1991).

The following species (by strata) are dominant and/or common:

Trees:	Dominant – variable when recorded as a stratum. Common – none commonly present.
Tall shrubs:	Dominant – variable acacias; A. *coolgardiensis, A. ramulosa* most frequently. Common – *A. acuminata,* subsp. *burkittii, A. coolgardiensis, A. ramulosa, A. tetragonophylla.*
Mid shrubs:	Dominant – very variable; commonly acacias. Common – *A. coolgardiensis, A. ramulosa, A. tetragonophylla.*
Low shrubs:	Dominant – very variable; acacias and ericoid shrub taxa. Common – none present.
Perennial grasses:	Dominant – *Amphipogon caricinus/strictus, Monachather paradoxa* (usually as facultative biennial). Common – *Stipa elegantissima.*
Other common plant forms:	*Cheilanthes* sp. (fern), *Dianella revoluta* (lily), *Thysanotus manglesianus* (climber).

Patterns of grazing impact

SACS is not particularly attractive to stock as it consists mainly of unpalatable species. Palatable perennial shrub densities are naturally variable. Curry *et al.* (1994) proposed >7 palatable perennial species/1000 m^2 as indicating Class 1 (best) condition, 4-7/1000 m^2 as Class 2 condition and <4/1000 m^2 as Class 3 (poor) condition. Soils are not usually susceptible to accelerated erosion due to the absence of substantial water movement and the protection against the wind provided by (unpalatable) tall shrubs.

Nature conservation

Patches of SACS occur on Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle *et al.* in prep) and on Mt Elvire station, which was acquired by the Department of Conservation and Land Management in May 1991. Some shrubs recorded include species important to conservation. These include Epacridaceae gen. sp. nov. and *Grevillea globosa* and further surveys are likely to reveal more rare and/or endangered sandplain species (Keighery *et al.* 1995).

Gradational associations

SACS resembles *Sandplain grassy bowgada shrubland* (SWGS) but has more diverse and denser acacias, less wanderrie grass cover and often has more ericoid shrubs. It may grade into acacia-spinifex associations (SAWS sub-type of SASP).

Land systems

Mainly Bannar, Joseph, Kalli and Yowie.

47. Lateritic sandplain acacia shrubland (LACS)

Sampling 13 inventory sites

General information

LACS is described here for the first time. It occurs on buff coloured sandplain and rises with pisolitic gravels which occur most extensively in the west of the survey area. In the centre, north and east of the survey area, LACS is usually restricted to narrow bands at the juxtaposition of sandplain and breakaway plateaux. In these locations, the sands are predominantly red and variously reworked aeolian sediments.

Physiognomy and composition of vegetation

LACS generally occurs as moderately close to close (20-50% projected foliar cover) tall shrubland with prominent low and mid shrub strata. Trees and perennial grasses may be present but are usually a minor component of the vegetation.

Eighty-one species were recorded at the 13 inventory sites at an average of 15 species per site, one fewer than the survey average. Species common to LACS are not unique to it. LACS commonly had genera usually associated only with sandplain and ironstone ridges (IRMS) and breakaway plateaux (BRXS); *Baeckea, Darwinia, Eriostemon, Hemigenia, Leucopogon, Malleostemon, Phebalium, Prostanthera, Thryptomene and Verticordia.*

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – rarely present as a stratum. Common – *Acacia aneura, Grevillea obliquistigma.*
Tall shrubs:	Dominant – very variable; usually acacias, *A. coolgardiensis, A. ramulosa* most frequent. Common – *A. aneura, A. coolgardiensis, A. ramulosa, A. tetragonophylla, G. obliquistigma.*
Mid shrubs:	Dominant – very variable. Common – *A. tetragonophylla, Eremophila clarkei, E. forrestii, E. latrobei* (KD).
Low shrubs:	Dominant – very variable; mainly ericoid species. Common – *Eremophila forrestii, Eriostemon brucei, Prostanthera althoferi, Ptilotus obovatus* (KD), *P. schwartzii* (KD).
Perennial grasses:	Dominant – rarely present as a stratum. Common – *Amphipogon caricinus/strictus, Monachather paradoxa, Stipa elegantissima.*

Patterns of grazing impact

LACS is not a preferentially grazed habitat as it consists overwhelmingly of unpalatable species. Nevertheless, species including *Eremophila latrobei, Ptilotus obovatus* and *P. schwartzii* may decline under heavy grazing. Soils are inherently stable, mainly owing to the protection afforded by shrub cover.

Nature conservation

The distinctive characteristic of the flora is the ericoid shrub understorey, most species of which appear to be unpalatable to stock, feral goats and kangaroos. As Keighery *et al.* (1995) observed, it is often in near pristine condition.

Gradational associations

LACS is similar to *Sandplain acacia shrubland* (SACS), but on 'lateritic' sands and generally has a richer ericoid understorey. It sometimes occurs in mosaics with heath, where soils tend to be shallower and have more gravel.

Land systems

Mainly Bannar, Nerramyne, Tallering, Tealtoo and Yowie.

48. Lateritic sandplain heath (LSHE)

Sampling 7 inventory sites

General information

LSHE is described for the first time. It occurs as very gravelly areas in buff coloured sandplain associated with laterite weathering profiles. Soils are usually gravelly sands over denser gravel. LSHE is distinctive in being a sandplain habitat dominated by low or mid shrubs rather than hummock grasses or tall shrubs, mallees and trees. Although LSHE occurs through most of the area, it is most extensive in the south.

Physiognomy and composition of vegetation

LSHE most often occurs as a moderately close (20–30% projected foliar cover) low or mid shrubland, sometimes with a well developed tall shrub stratum. Perennial grasses are not generally conspicuous. Seventy–one species were recorded at the seven inventory sites at an average of 14 species per site, two fewer than the survey average. Six species were only recorded and a further eight were recorded in only one other habitat, making up 20% of all species, indicating a high uniqueness of the flora relative to other habitats. The survey average is 9.8% of all species to be unique to each habitat, or nearly so, as defined. Only *Acacia steedmanii, Allocasuarina corniculata* and *Pseudanthus* sp. were collected twice, the rest were single records.

The following species (by strata) are dominant and/or common:

Trees:	Rarely present.
Tall shrubs:	Dominant – very variable; *Acacia* or *Allocasuarina* spp. Common – *Acacia aneura, A. coolgardiensis.*
Mid shrubs:	Dominant – variable; *Acacia* or *Myrtaceae.* Common – *A. coolgardiensis, Baeckea* aff. *uncinella, Eremophila forrestii.*
Low shrubs:	Dominant – variable; often *Myrtaceae.* Common – *Baeckea* aff. *uncinella, Eremophila forrestii.*
Perennial grasses:	Dominant – not commonly recorded. Common – *Amphipogon caricinus/strictus, Monachather paradoxa* (facultative biennial).
Other common plant forms:	*Dianella revoluta* (lily).

The shrub flora contained species distinctive of this group of habitats, as well as more ecologically widespread species such as *A. aneura* and *E. forrestii.* The main genera with species representative of this distinctive flora include *Acacia, Allocasuarina, Baeckea, Chamelaucium, Epacridaceae* gen. nov., *Melaleuca, Phebalium, Prostanthera* and *Thryptomene.*

Patterns of grazing impact

This vegetation is little altered by grazing because it is unattractive to livestock.

Nature conservation

Grazing is not a major threat to this habitat. The distinctive flora includes species of particular conservation value including *Calothamnus superbus* (P1), *Epacridaceae* gen. sp. nov (P1), *Hemigenia brachyphylla* (P2) and *Leucopogon breviflorus* (P2).

Gradational associations

LSHE is a distinctive habitat that grades into *Lateritic sandplain acacia shrubland* (LACS) as acacia tall shrubs become more prominent on deeper soils.

Land systems

Mainly Bannar, also Joseph, Kalli and Marmion.

49. Sandplain close mixed shrubland (SCMS)

Sampling 14 inventory sites

General information

SCMS is described here for the first time. It usually occurs on gently undulating yellow sandplains in the south of the survey area. Its flora is quite different at species level to Eremaean sandplain communities. While not particularly susceptible to wildfires, occasional burnt areas appear to have carried intense and extensive (low) canopy fires that left few surviving shrubs.

SCMS appears to have been a favoured habitat for wheat in the agricultural areas abutting the survey area; and very small areas had been 'parkland' cleared on some pastoral stations to promote improved introduced pastures or crops.

Physiognomy and composition of vegetation

SCMS consists of close or closed (>30% projected foliar cover), occasionally only moderately close (25–30% projected foliar cover) shrubland, often dominated by tall shrubs but sometimes by low or mid shrubs. Trees and perennial grasses are not generally as well represented, although a perennial grass stratum is sometimes present. Patches of mallees (e.g. *Eucalyptus leptopoda*) are sometimes present.

One hundred-and-eighteen species were recorded at the 14 inventory sites at an average of 15 species per site, one less than the survey average. A third of all species were either only recorded in it (23 species) or in only one other habitat as well (16). This is a particularly high level of floral distinctiveness. The following species were recorded more than once: *Allocasuarina corniculata* (2 records), *Calothamnus* sp. (2), *Eriostemon deserti* (3), *Hakea scoparia* (3), *Melaleuca cordata* (6) and *Wehlia thryptomenoides* (3). While *Wehlia thryptomenoides* is common in the arid interior

(Beard 1991), species such as *Melaleuca cordata* and *Hakea scoparia* are more closely associated with the South-West Botanical Province and in particular with the sandy terrain of the wheatbelt.

The following species (by strata) are dominant and/or common:

Trees:	Dominant – not usually present. Common – *Melaleuca uncinata.*
Tall shrubs:	Dominant – variable; acacias most common; also *Allocasuarina , Melaleuca* spp. Common – *Acacia coolgardiensis, A. sibina, Melaleuca uncinata.*
Mid shrubs:	Dominant – very variable; acacias or heath shrubs. Common – *Baeckea* sp., *Melaleuca cordata, Malleostemon tuberculatus, Phebalium canaliculatum.*
Low shrubs:	Dominant – very variable; heath shrubs. Common – *Baeckea* sp., *Melaleuca cordata, Malleostemon tuberculatus, Phebalium canaliculatum.*
Perennial grasses:	Dominant – *Amphipogon caricinus/strictus.* Common – no other common species.
Other common plant forms:	*Dianella revoluta* (lily), *Ecdeiocolea monostachya* (Restionaceae), *Thysanotus manglesianus* (climber).

Pattern of grazing impacts

SCMS consists almost entirely of species not usually grazed by stock. Dense (unpalatable) vegetation provides effective protection against wind erosion.

Nature conservation

Much appears to have been cleared for cropping in the adjacent wheatbelt. SCMS is not particularly threatened by grazing, much of it is undeveloped or outside pastoral leases.

Gradational associations

SCMS is most similar to *Sandplain acacia shrubland* (SACS), but often having denser vegetation with conspicuous floristic components associated more with the South-West Botanical than the Eremaean Province.

Land systems

Most extensive in Joseph; also Bannar, Euchre, Olympic and Yowie.

50. Sandplain with mallees and acacias (MAAS)

Sampling 21 inventory sites

General information

MAAS is described here for the first time. It occurs on deep (>60 cm) sandy soils on broad, nearly level to very gently undulating plains commonly encountered in an arc from the north-west corner of the survey southwards and then eastwards along the southern half. Further north, spinifex hummock grasses tend to dominate these land surfaces.

Physiognomy and composition of vegetation

MAAS generally consists of moderately close (20–30% projected foliar cover) tall shrubland with a prominent, sometimes dominant, mallee component. Lower strata are common but generally clearly subordinate. One hundred and thirty–three species were recorded at the 21 inventory sites, at an average of 20, four more than the survey average. Most of these are also common in other sandy habitats.

The following species (by strata) are dominant and/or common:

Trees and mallees:	Dominant – very variable; *Eucalyptus leptopoda, E. longicornis, E. loxophleba* most common. Common – *Acacia aneura, Callitris glaucophylla.*
Tall shrubs:	Dominant – variable; mostly acacias including *A. coolgardiensis, A. ramulosa.* Common – *A. aneura, A. acuminata* subsp. *burkittii, A. coolgardiensis, A. ramulosa, A. tetragonophylla, Hakea recurva.*
Mid shrubs:	Dominant – variable; mostly acacias including *A. coolgardiensis, A. ramulosa.* Common – *A. coolgardiensis, A. ramulosa, A. colletioides, A. tetragonophylla, Eremophila eriocalyx* (KD), *Rhagodia eremaea.*
Low shrubs:	Dominant – very variable. Common – *Senna artemisioides* subsp. *filifolia, Eremophila eriocalyx* (KD), *Maireana villosa, Olearia pimeleoides, Ptilotus obovatus, Rhagodia eremaea.*
Perennial grasses:	Dominant – variable. Common – *Amphipogon caricinus/strictus, Monachather paradoxa, Stipa elegantissima.*
Other common plant forms:	*Dianella revoluta* (lily).

The understorey component varied according to soil type and drainage. On marginally heavier sandy soils receiving diffuse run–on, species associated with *Acacia aneura* plains were common. These include *Enchylaena tomentosa, Eremophila forrestii, Maireana* spp., *Ptilotus obovatus, Rhagodia eremaea, Scaevola spinescens* and *Sida calyxhymenia*. On the very sandy soils, ericoid and associated species typical of heath communities were common. They include *Eriostemon thryptomenoides, Hemigenia* spp., *Phebalium canaliculatum* and *Prostanthera* sp.

Patterns of grazing impact

MAAS is not a preferred grazing habitat, however in run–on sites, species including *Enchylaena tomentosa* and *Eremophila eriocalyx* may be removed. Negligible surface drainage and moderately close, largely unpalatable vegetation confer soil stability.

Nature conservation

Most species are common to other habitats and none of particular conservation value were recorded.

Gradational associations

Conspicuous combination of mallees on sandplain make MAAS distinctive.

Land systems

Mainly Bannar, Joseph, Kalli, Pindar, Tyrrell and Yowie.

Other minor habitats in 'sandplain sclerophyll shrubland or woodland habitat' group

Sand dune shrubland (SDSH)
– 2 inventory sites

Sand dunes occur most frequently in the extensive red aeolian sand sheets in the north-east of the survey area on the Youanmi and Sandstone 1:250,000 scale map sheets. They are usually 5 to 20 m high and can extend for kilometres although they are usually a few hundred metres long. Vegetation is characteristically very variable, even from one dune to the next. They range from *Eucalyptus gongylocarpa* woodlands to spinifex hummock grass communities.

They may support any combination of the following major components:

Trees:	*Eucalyptus gongylocarpa, Callitris preissii* subsp. *verrucosa.*
Mallees:	*Eucalyptus kingsmillii, E. leptopoda.*
Tall shrubs:	*Acacia coolgardiensis, A. ligulata, Duboisia hopwoodii, Grevillea juncifolia, Hakea minyma.*
Mid shrubs:	*Senna artemisioides* subsp. *filifolia, Eremophila forrestii, Phebalium canaliculata, Rhagodia eremaea.*
Low shrubs:	*Alyogyne pinoniana, Baeckea cryptandroides, Anthotroche pannosa, Bonamia rosea, Dicrastylis* spp. *Eremophila forrestii, Eriostemon brucei, Helipterum adpressum, Newcastelia hexarrhena, Solanum plicatile, Thryptomene* spp.
Perennial grasses:	*Amphipogon caricinus/strictus, Eragrostis eriopoda, Eriachne helmsii, Pletrachne rigidissima, Triodia basedowii.*
Other plant forms:	*Dianella revoluta* (lily), *Lomandra leucocephata* (sedge-like Dasypogonaceae).

Sand dunes often support a rich vertebrate fauna, particularly in dune swales and thus have considerable conservation value. There are several well developed sand dunes on Wanjarri Nature Reserve in the adjacent north-eastern Goldfields rangeland survey area (Pringle *et al*. in prep.).

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Land systems

A.L. Payne, A.M.E. Van Vreeswyk and H.J.R. Pringle

Diagrams by K.A. Leighton

Within the survey area 76 land systems have been identified, 18 of which are described for the first time, and the other 58 having been described previously in adjacent surveys. The land systems are derived from aerial photography and descriptions are built up using field data collected during traversing and at inventory sites.

Land systems are grouped into land types according to a combination of landforms, soils, vegetation and drainage patterns. Table 1 shows the land types and their component land systems. This amalgamation of the 76 land systems into 20 categories provides a simpler mechanism to colour code the accompanying 1:500 000 scale map, and provides information at a more appropriate level when planning at a regional scale.

The location of each inventory site, with the site number and a code for the land unit on which it occurred, are shown on the land system map. Table 2 gives a list of land units with the codes used on the maps.

Land systems are described in alphabetical order in this chapter. A summary description of each system's major features is followed by more detailed accounts of the units that comprise each system. The format used for the summary descriptions is:

- land system name, area and percentage of the survey area
- reference to any previous description
- brief descriptive statement of dominant landform(s) and vegetation
- land type (refer to Table 1)
- major geological formation or land surface types
- geomorphology overview
- brief discussion of land management considerations such as susceptibility to soil erosion
- traverse condition summary
- the extent of area mapped as severely degraded and eroded (sde)
- a locality map showing the distribution of the land system and the 1:250 000 map sheet reference
- a plan or block diagram showing the physical features of the system, and with each land unit identified
- a list of the land units, normally in order of highest to lowest position in the landscape, with the number of sampling points. Not all units in each land system are shown in diagrams or described in the tables. Minor units that were encountered very occasionally whilst traversing the land system are listed as 'other' in the summary table.

On each opposing page a summary of the biophysical components for each land unit provides additional detail:

- unit area, estimated from aerial photo interpretation and field observation, is presented as a percentage of the total land system area
- landform - lists each land unit with a description of the landform
- soils - generalised description with reference to the appropriate soil grouping (refer to the Soils chapter)
- vegetation - the vegetation is described in four parts: cover density (with projected foliar cover -PFC); dominant species; height class and formation (e.g. shrubland, grassland, etc.). Four letter codes for the habitats (refer to the Ecological Assessment chapter) are listed.

Table 1. Land types and their land systems

Land type	Description and land systems
1	Hills with acacia shrublands Land systems – Bevon, Brooking, Gabanintha, Mulline, Naluthanna, Norie, Teutonic, Watson and Wiluna
2	Hills with mixed shrublands Land systems – Dryandra, Singleton and Tallering
3	Low hills with eucalypt-halophyte woodlands and acacia shrublands Land systems – Graves and Lawrence
4	Breakaways, stony plains and sandy surfaced plains on granite with mulga shrublands and minor halophytic shrublands Land systems – Euchre, Narryer, Olympic, Sherwood and Waguin
5	Breakaways and alluvial plains with predominantly saline soils and halophytic shrublands Land systems – Gumbreak, Hootanui and Yilgangi
6	Plains with gritty surfaces and low tors and domes on granite with acacia shrublands Land systems – Bandy and Challenge
7	Irregular plains and low rises supporting mulga, bowgada and some halophytic shrublands Land systems – Nerramyne, Nubev and Violet
8	Stony plains and lower alluvial plains with predominantly saline soils and halophytic shrublands Land systems – Austin, Gransal, Moriarty and Nallex
9	Stony plains and occasional low rises with acacia-eremophila shrublands Land systems – Felix, Windarra and Yarrameedie
10	Sandplains with spinifex hummock grasslands Land systems – Bullimore, Marmion and Tyrrell
11	Sandplains with acacia shrublands, mallees and heath Land systems – Bannar and Joseph
12	Sandplains with grassy acacia shrublands Land systems – Kalli
13	Wash plains on hardpan with mulga shrublands Land systems – Hamilton, Jundee, Rainbow, Ranch, Tindalarra, Woodline and Yalluwin
14	Wash plains and sandy tracts on hardpan, with mulga shrublands and wanderrie grasses Land systems – Bunny, Monk and Yanganoo
15	Wash plains on hardpan with mixed halophytic and non-halophytic shrublands Land systems – Marlow, Monitor and Tango
16	Plains with deep sandy soils supporting acacia shrublands and occasionally with wanderrie grasses Land systems – Ararak, Desdemona, Illaara, Tealtoo and Yowie
17	Alluvial plains with saline soils and predominantly with halophytic shrublands Land systems – Campsite, Ero, Joy, Merbla, Racecourse, Roderick, Skipper, Steer, Wilson and Yewin
18	Calcreted drainage plains with mixed halophytic and non-halophytic shrublands Land systems – Cosmo, Cunyu, Melaleuca and Mileura
19	Plains with minor calcrete inclusions with casuarina-acacia shrublands or eucalypt woodlands Land systems – Deadman, Doney and Pindar
20	Salt lakes and fringing alluvial plains with halophytic shrublands Land systems – Carnegie

Table 2. Land units and their code

Code	Land unit
BAS	sandy bank
BRX	breakaway
CAP	calcrete platform
CHJ	major channel (> 10 m wide)
CHM	minor channel (< 10 m wide)
CLA	claypan
DOM	granite dome
DRF	drainage focus
DRN	narrow drainage line (< 0.5 km)
DRW	wide drainage line (> 0.5 km)
DUN	sand dune
FAA	alluvial fan
FOL	lower footslope
FOO	footslope
FOU	upper footslope
GRO	grove
HCR	hillcrest
HIL	hill
HSL	hillslope
KOP	kopi dune
LAB	lake bed
LAM	lake margin
LEV	levee
PGC	calcareous stony plain
PGI	stony gilgai plain
PGR	gritty-surfaced plain with shallow soil on granite
PGS	saline stony plain
PHG	stony hardpan plain
PHL	gravelly hardpan plain
PHS	saline hardpan plain
PLA	saline alluvial plain
PLC	calcrete plain with calcrete rubble
PLF	floodplain
PLG	stony plain
PLH	hardpan plain
PLI	gilgai plain
PLL	gravelly plain with sandy soils
PLO	plain with sandy loam soil
PLS	highly saline plain
PSL	gravelly saline alluvial plain
PTX	plateau
RDG	ridge
RIL	low rise
SCF	scarp face
SSH	sand sheet or plain
SSL	gravelly sand sheet
SSU	stripped surface
SWA	swale
SWP	swamp
TER	terrace
TOR	low hill consisting of boulders/core stones

Sampling intensity

Table 3 indicates the area and intensity of sampling on each system in the survey area. A summary of the condition of each land system is presented in the resource condition chapter.

Table 3. Land system areas and sampling intensity

Land system	Area (km^2)	Per cent of total area total area	No. of inventory sites	Traverse sampling intensity		
				No. of assessments	Density index*	Sq km per rating
Ararak	67	0.1	0	5	0.72	13
Austin	5	<0.01	0	Not traversed	0.00	0
Bandy	638	0.7	6	54	0.82	12
Bannar	6,937	7.3	23	370	0.52	19
Bevon	314	0.3	3	19	0.59	16
Brooking	366	0.4	7	32	0.85	11
Bullimore	6,249	6.6	9	238	0.37	26
Bunny	16	0.02	0	Not traversed	0.00	0
Campsite	173	0.2	9	29	1.62	6
Carnegie	8,649	9.1	43	578	0.65	15
Challenge	3,655	3.9	22	458	1.21	8
Cosmo	50	0.05	1	10	1.93	5
Cunyu	358	0.4	14	96	2.59	4
Deadman	214	0.2	5	39	1.80	5
Desdemona	40	0.04	0	3	0.73	13
Doney	1,287	1.4	20	135	1.01	10
Dryandra	353	0.4	6	33	0.90	11
Ero	531	0.6	22	139	2.53	4
Euchre	1,769	1.9	30	198	1.08	9
Felix	112	0.1	3	19	1.64	6
Gabanintha	1,145	1.2	21	104	0.90	11
Gransal	800	0.8	14	190	2.30	4
Graves	172	0.2	4	25	1.41	7
Gumbreak	382	0.4	10	66	1.67	6
Hamilton	325	0.3	7	71	2.11	5
Hootanui	423	0.4	25	94	2.15	4
Illaara	202	0.2	5	21	1.00	10
Joseph	4,612	4.9	19	297	0.62	16
Joy	19	0.02	4	6	3.05	3
Jundee	1,333	1.4	9	186	1.35	7
Kalli	4,954	5.2	20	445	0.87	11
Lawrence	4	<0.01	0	Not traversed	0.00	0
Marlow	137	0.1	9	36	2.54	4
Marmion	4,150	4.4	7	124	0.29	33
Melaleuca	129	0.1	7	14	1.05	9
Merbla	360	0.4	19	70	1.88	5
Mileura	700	0.7	34	194	2.69	4
Monitor	66	0.1	3	21	3.08	3
Monk	1,822	1.9	11	265	1.41	7
Moriarty	825	0.9	26	129	1.51	6
Mulline	78	0.1	4	17	2.11	5
Nallex	439	0.5	18	99	2.18	4
Naluthanna	277	0.3	10	30	1.05	9
Narryer	19	0.02	0	Not traversed	0.00	0
Nerramyne	1,650	1.7	23	181	1.07	9
Norie	755	0.8	6	36	0.46	21
Nubev	133	0.1	2	35	2.54	4
Olympic	1,135	1.2	20	131	1.10	9
Pindar	1,519	1.6	18	128	0.81	12
Racecourse	53	0.1	4	10	1.82	5

Table 3. continued

Land system	Area (km^2)	Per cent of total area total area	No. of inventory sites	Traverse sampling intensity No. of assessments	Density index*	Sq km per rating
Rainbow	666	0.7	4	107	1.56	6
Ranch	298	0.3	6	52	1.69	6
Roderick	47	0.05	3	13	2.67	4
Sherwood	3,458	3.7	28	421	1.18	8
Singleton	238	0.3	3	26	1.06	9
Skipper	19	0.02	3	2	1.02	9
Steer	133	0.1	3	11	0.80	12
Tallering	329	0.3	12	29	0.85	11
Tango	86	0.1	6	25	2.81	3
Tealtoo	693	0.7	12	102	1.42	7
Teutonic	78	0.1	4	5	0.62	16
Tindalarra	4,349	4.6	24	716	1.59	6
Tyrrell	1,960	2.1	9	180	0.89	11
Violet	882	0.9	9	123	1.35	7
Waguin	1,249	1.3	15	129	1.00	10
Watson	155	0.2	4	12	0.75	13
Wilson	37	0.04	5	26	6.80	1
Wiluna	386	0.4	18	57	1.43	7
Windarra	370	0.4	4	59	1.54	6
Woodline	5,856	6.2	20	733	1.21	8
Yalluwin	247	0.3	6	36	1.41	7
Yanganoo	3,276	3.5	16	513	1.51	6
Yarrameedie	66	0.1	2	28	4.10	2
Yewin	140	0.1	5	23	1.59	6
Yilgangi	21	0.02	2	3	1.38	7
Yowie	9,189	9.7	41	879	0.93	10
Totals	94,629		846	9,790	1.00	9.67

* Density index: measure of sampling intensity relative to the mean (1.00) of the survey area

ARARAK LAND SYSTEM (67 km², 0.1% of the survey area)

(after Pringle *et al.* 1994)

Broad plains with mantles of ironstone gravel supporting mulga shrublands with wanderrie grasses.

Land type: 16

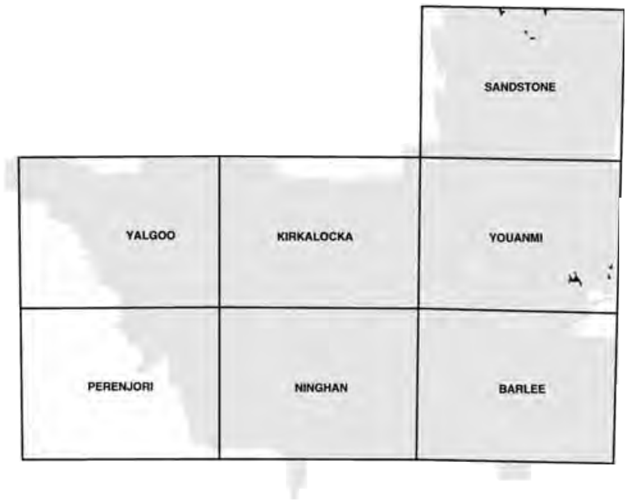
Geology: Quaternary alluvium and sand with minor Tertiary limonite.

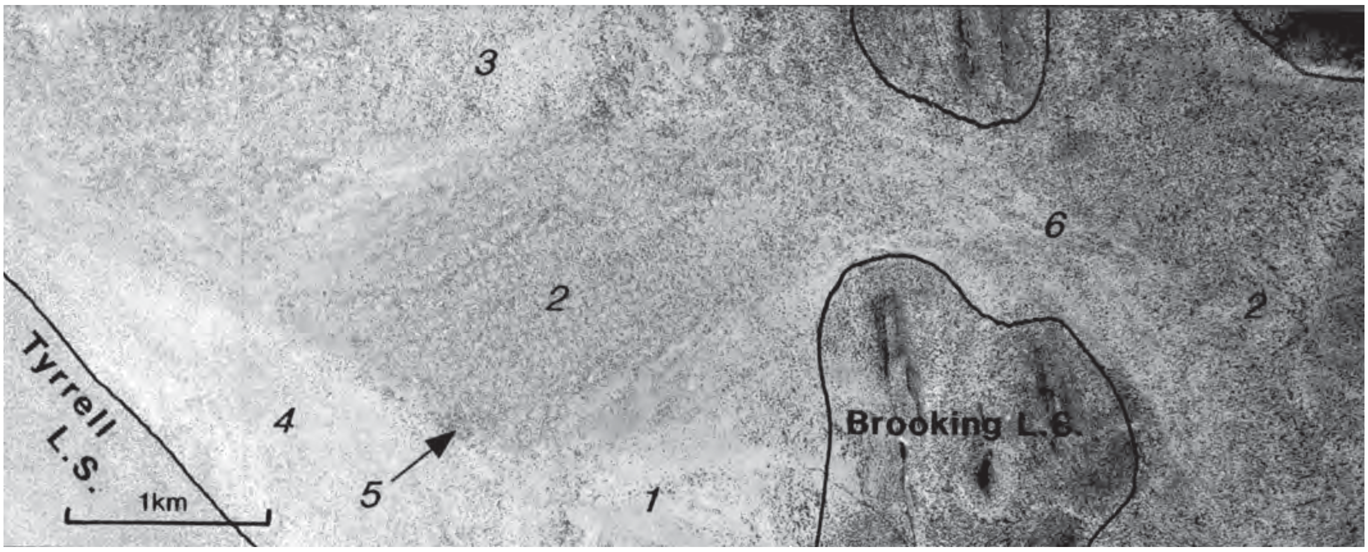
Geomorphology: Depositional surfaces; extensive level to gently undulating plains subject to very diffuse sheet flow, more concentrated flow zones, isolated rises with limonite (<5 m relief) and higher plains with pebble mantles.

Land management: As a result of low slopes, protective soil mantles and very diffuse sheet flow, this land system is generally not susceptible to soil erosion. It is only mildly susceptible to water starvation problems (and consequent loss of vigour in vegetation).

Traverse condition summary (5 ratings):
Vegetation – insufficient assessments.
Soil erosion – insufficient assessments.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Stony plain	1	–
2	Gravelly sandy plain	–	–
3	Loamy plain	3	–
4	Hardpan plain	1	–
5	Groves in hardpan plain	–	–
6	Narrow drainage tract	–	–
	Total	5	0

Ararak land system

Unit area (%)	Landform	Soil	Vegetation
1. 3%	**Stony plains** – very gently to gently inclined plains with a mantle of quartz and ironstone pebbles downslope from erosional land systems.	Shallow red earths on greenstone (5c).	Very scattered to scattered (2.5-20% PFC) tall *Acacia aneura* (mulga) tall shrublands (SAES).
2. 50%	**Gravelly sandy plains** – nearly level to gently undulating plains with mantles of ironstone gravel, subject to very diffuse sheet flow.	Deep red earths or shallow red clayey sands with ferruginous gravel (6a, 2).	Scattered (10-20% PFC) *A. aneura* tall shrubs in wanderrie grasslands with occasional *Triodia basedowii* (hard spinifex) (mainly MUWA).
3. 22%	**Loamy plains** – level plains subject to very diffuse run-on.	Deep red earths, sandy surfaced red earths, occasionally deep red clayey sands (6a, 4, 3a).	Scattered (10-20% PFC) *A. aneura* tall shrubs with a wanderrie grass ground layer (MUWA), occasionally with hummock grasses (SAMU).
4. 20%	**Hardpan plains** – level to very gently inclined plains subject to sheet flow, occasional mantle of quartz or ferruginous pebbles.	Shallow red earths on hardpan (5c).	Very scattered to scattered (2.5-20% PFC) *A. aneura* tall shrublands (HPMS, LHMS).
5. 1%	**Groves** – arcuate, contour aligned drainage foci within unit 4, often about 50 m wide and 200 m long.	Deep red earths occasionally on hardpan (6a).	Moderately close to close (20-50% PFC) *A. aneura* tall shrublands (GRMU).
6. 4%	**Narrow drainage tracts** – sparse, generally unidirectional, poorly defined narrow drainage tracts.	Shallow red earths on greenstone or shallow clays (4b, 5b, 6a, 9a).	Scattered (10-20% PFC) *A. aneura* tall shrublands (HPMS).

AUSTIN LAND SYSTEM (5 km^2, <0.01% of the survey area)

(after Curry *et al.* 1994)

Saline stony plains with low rises and drainage foci supporting low halophytic shrublands with scattered mulga.

Land type: 8

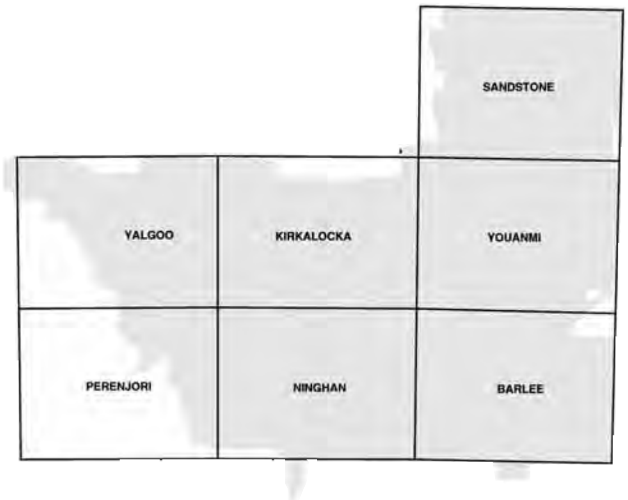
Geology: Quaternary colluvium and alluvium with isolated Precambrian greenstone intrusions and Archaean granitic outcrops.

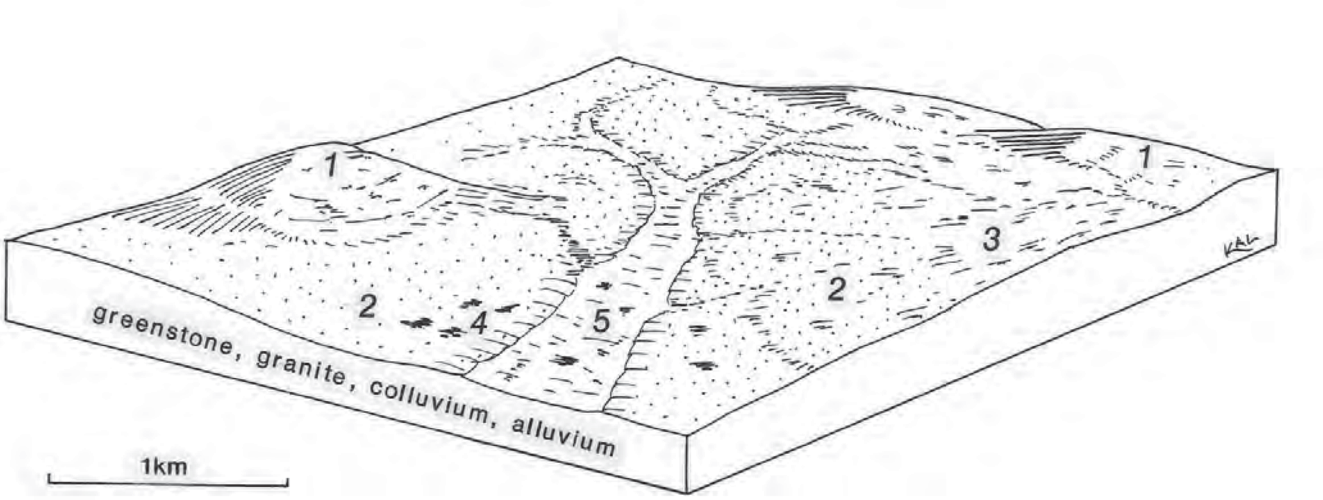
Geomorphology: Mainly depositional surfaces; gently undulating saline stony plains with scattered drainage foci and associated internal sluggish drainage lines; low rises and ridges up to 20 m high, but generally 5 to 10 m.

Land management: Preferential overgrazing of drainage tracts can lead to increased erosion.

Traverse condition summary: Not traversed.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Low ridge/rise	–	–
2	Saline stony plain	–	–
3	Stony plain	–	–
4	Drainage focus	–	–
5	Drainage tract	–	–
	Total	0	0

Austin land system

Unit area (%)		Landform	Soil	Vegetation
1.	5%	**Low ridges and rises** – low ridges of outcropping granite, quartz or greenstone and low rises, up to 800 m long and 2-25 m high, and short footslopes with abundant mantles of cobbles and pebbles.	Shallow red earths and shallow duplex soils on granite or greenstone (4b, 5c, 7a, 7b).	Scattered (10-20% PFC) shrublands or woodlands usually dominated by *Acacia aneura* (mulga) (SIMS).
2.	80%	**Saline stony plains** – gently undulating plains extending up to 3 km, commonly with mantles of abundant to very abundant quartz or ironstone pebbles.	Shallow duplex soils on greenstone (7b).	Very scattered to scattered (2.5-20% PFC) *Maireana* spp. low shrublands (SBMS), *Maireana* species include *M. pyramidata* (sago bush), *M. glomerifolia* (ball-leaf bluebush), *M. georgei* (George's bluebush) and *M. triptera* (three-winged bluebush).
3.	10%	**Stony plains** – gently undulating plains within or above unit 2; quartz and granite pebble mantles and occasional granite outcrop.	Shallow red earths on granite (5c).	Very scattered to scattered (2.5-20% PFC) low shrublands (SGRS).
4.	<1%	**Drainage foci** – small discrete (10-50 m in diameter) depositional zones, occurring sparsely within units 2 and 5.	Red clays of variable depth on hardpan or parent rock (9a, 9b).	Moderately close to close (20-50% PFC) acacia woodland or tall shrubland; dominant species are *A. aneura* and *A. tetragonophylla* (curara) (GRMU).
5.	5%	**Drainage lines** – very gently inclined linear drainage tracts, mostly unchannelled but occasionally incised with rills, gutters and shallow gullies; variable mantles of ironstone and quartz pebbles.	Deep red earths (6a).	Very scattered (2.5-10% PFC) *A aneura* low woodland or tall shrubland (HPMS) or scattered *Maireana* spp. low shrubland.

BANDY LAND SYSTEM (638 km², 0.7% of the survey area)

(after Pringle *et al.* 1994)

Gritty-surfaced plains and low outcrops of granite with scattered acacia shrublands.

Land type: 6

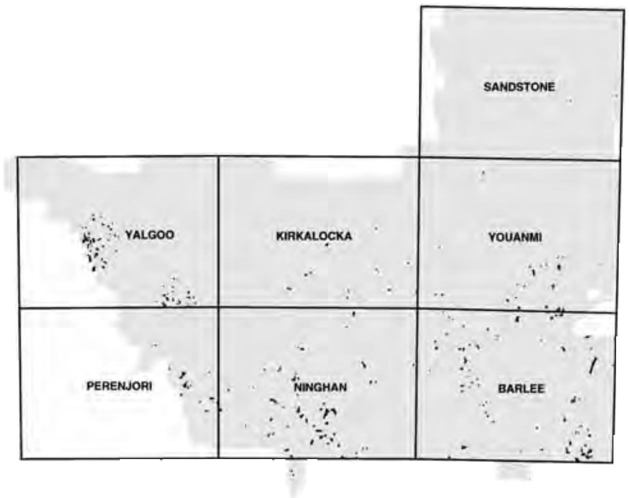
Geology: Archaean granite and Quaternary colluvium.

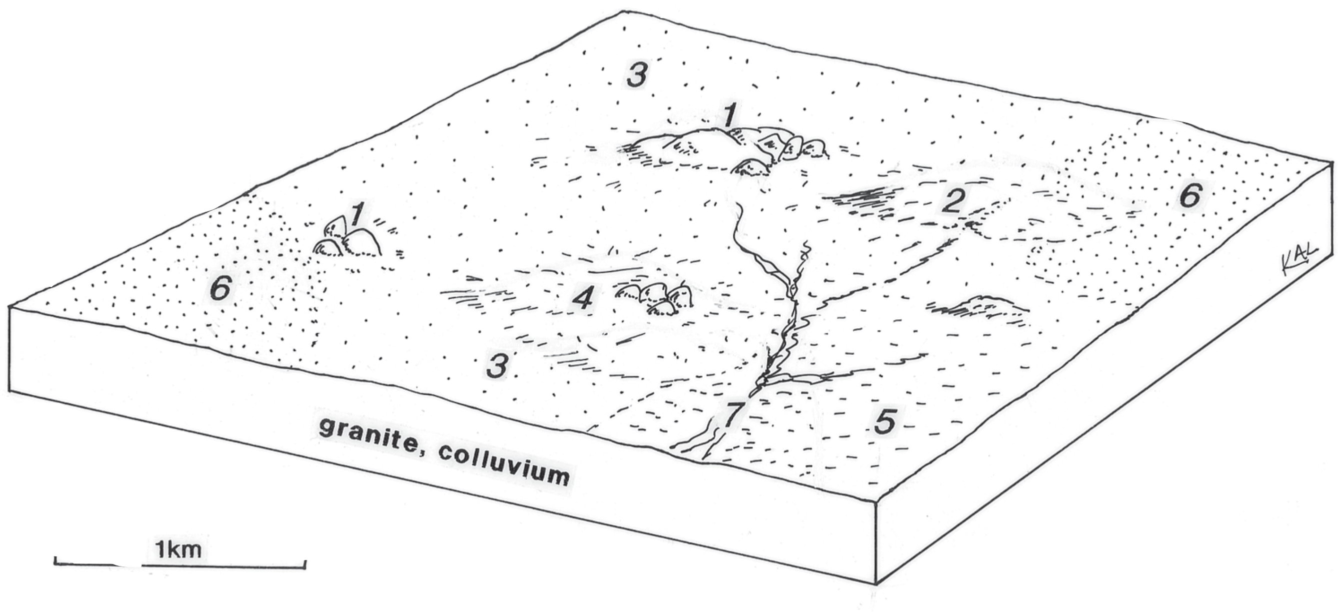
Geomorphology: Mainly erosional surfaces; low outcrops and gritty-surfaced and stony plains interspersed with lower plains subject to diffuse sheet flow; occasional sand sheets.

Land management: This land system is not generally susceptible to soil erosion.

Traverse condition summary (51 assessments):
Vegetation – good 69%; fair 25%; poor 6%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Dome	1	1
2	Low rise	1	–
3	Gritty-surfaced plain	23	3
4	Stony plain	1	1
5	Loamy plain	18	–
6	Sand sheet	8	–
7	Drainage line	2	1
	Total	54 *	6

* 3 traverse points not assessed for condition.

Bandy land system

Unit	area (%)	Landform	Soil	Vegetation
1.	2%	**Domes** – low granite outcrops and tor fields.	Soil confined to pockets of detrital sand (2a).	Mostly unvegetated, isolated shrubs such as *Acacia quadrimarginea* (granite wattle) and *Kunzea pulchella*.
2.	5%	**Low rises** – low rises (about 5 m relief) with common granite outcrop.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) acacia-eremophila tall shrublands (GRHS).
3.	45%	**Gritty-surfaced plains** – level to gently undulating plains with sandy-surfaces and some granite outcrop and quartz or granite gravel, adjacent to tor fields and low rises.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) *Acacia quadrimarginea* tall shrubland (SGRS), or scattered acacia tall shrubland with *Borya sphaerocephala* low shrubs (GABS).
4.	5%	**Stony plains** – gently undulating plains with granite rubble and weathered granite outcrop.	Shallow red earths on granite (5c).	Scattered (10-20% PFC) acacia-eremophila tall shrublands (SAES).
5.	28%	**Loamy plains** – level to gently undulating plains.	Deep red clayey sands or shallow red earths on granite (3a, 5c).	Scattered to moderately close (10-30%) *Acacia aneura* (mulga) tall shrublands with scattered wanderrie grasses (PLMS, MUBW).
6.	15%	**Sand sheet** – gently undulating plains.	Deep or shallow red clayey sands on granite (3a, 2d).	Scattered (10-20% PFC) *Acacia coolgardiensis* (sugar brother) and *A. aneura* tall shrublands with spinifex grass layer (SACS).
7.	<1%	**Drainage lines** – narrow drainage tracts flanking unit 1.	Shallow red clayey sands over granite (2d).	Close (30-50% PFC) mallee – acacia tall shrubland (CBKW).

BANNAR LAND SYSTEM (6,937 km^2, 7.3% of the survey area)

Level to gently undulating sandy plains with acacia shrublands, commonly with patchy native pines and mallees.

Land type: 11

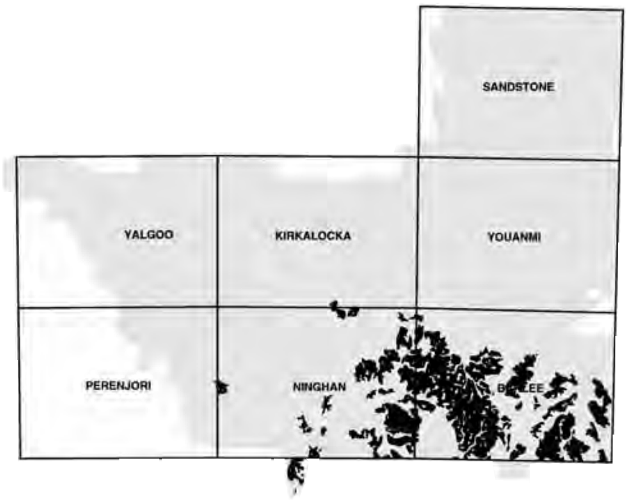
Geology: Cainozoic sand and Tertiary laterite.

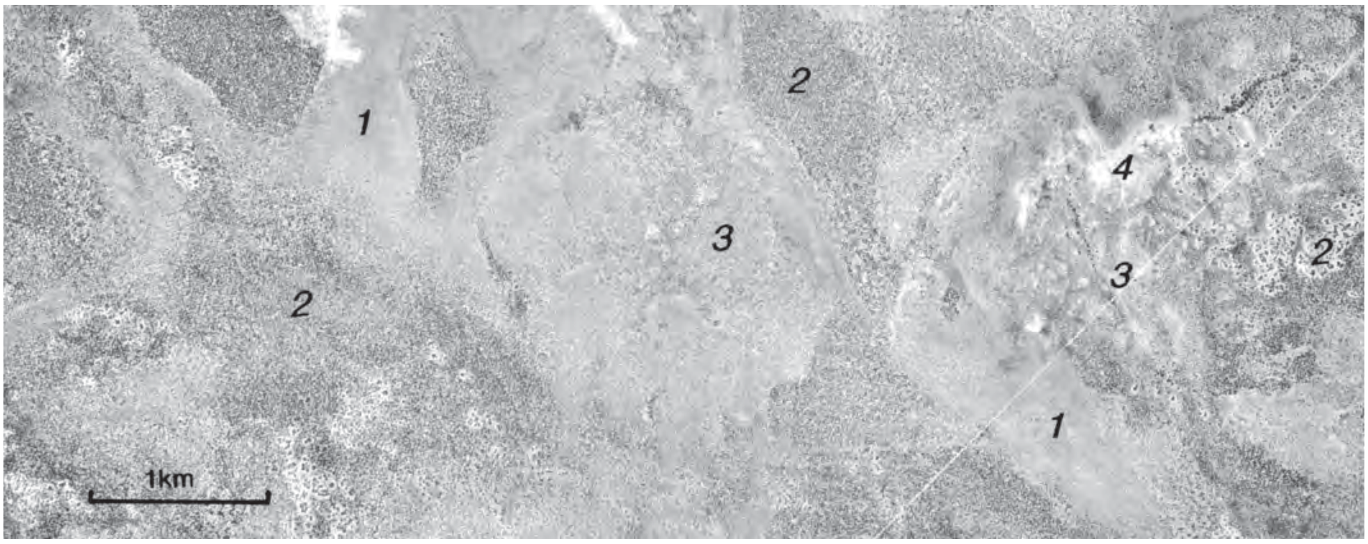
Geomorphology: Depositional surfaces; level to gently undulating sandplains, with common areas of plains receiving diffuse run-on.

Land management: The soils of this system have an inherently low susceptibility to erosion because of their coarse surface texture.

Traverse condition summary (362 assessments):
Vegetation – good 88%; fair 9%; poor 2%; very poor 1%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Gravelly sand sheet	53	9
2	Sand sheet	181	10
3	Loamy plain	118	4
4	Stony plain	16	–
	Other	2	–
	Total	370 *	23

* 8 traverse points not assessed for condition.

Bannar land system

Unit area (%)	Landform	Soil	Vegetation
1. 15%	**Gravelly sand sheets** – level sand sheets with mantles of few to abundant small to medium subrounded ironstone gravel.	Shallow red or yellow clayey sands on ironstone gravel (2d, 2e).	Moderately close to closed (20- > 50% PFC) acacia tall shrubland or moderately close heath low shrubland (LACS, LSHE) or moderately close to close casuarina and acacia tall shrubland with mallee eucalypts (SCMS).
2. 50%	**Sand sheets** – level to gently undulating sand sheets.	Deep red or yellow clayey sands (3a, 3b).	Moderately close to close (20-50% PFC) *Callitris glaucophylla* (native pine) woodland or tall shrubland (PINW), close *Acacia coolgardiensis* (sugar brother) tall shrubland with mallees and low heath shrubs (SACS, MAAS), or occasionally *Triodia basedowii* (hard spinifex) hummock grasslands with mallee eucalypt overstoreys (SASP).
3. 30%	**Loamy plains** – level plains, may have very few to few subrounded small ironstone pebbles.	Deep red earths or shallow red earths on gravel (4, 5c).	Moderately close to close (20-50% PFC) *Callitris glaucophylla* and acacia tall shrublands/woodland (PINW), acacia tall shrublands with and without mallees (MAAS, PLMS), *Eucalyptus loxophleba* (York gum) woodland with mixed low shrubs and acacia tall shrubs (PYAW).
4. 5%	**Stony plains** – plains and partly stripped surfaces with thin sand cover and variable density mantles of ironstone or silcrete pebbles.	Shallow red clayey sands on gravel (2d).	Scattered to moderately close (10-30% PFC) tall acacia shrublands (SGRS), occasionally very scattered to scattered (2.5-20% PFC) low shrubland (BRXS).

BEVON LAND SYSTEM (314 km², 0.3% of the survey area)

(after Pringle *et al.* 1994)

Dissected uplands with mulga shrublands.

Land type: 1

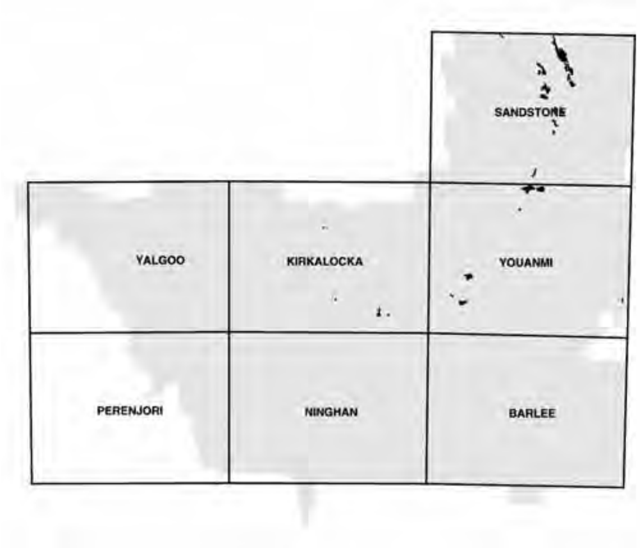
Geology: Tertiary limonite, minor Archaean greenstone and banded iron formation, Quaternary colluvium and restricted areas of Quaternary alluvium and eluvium.

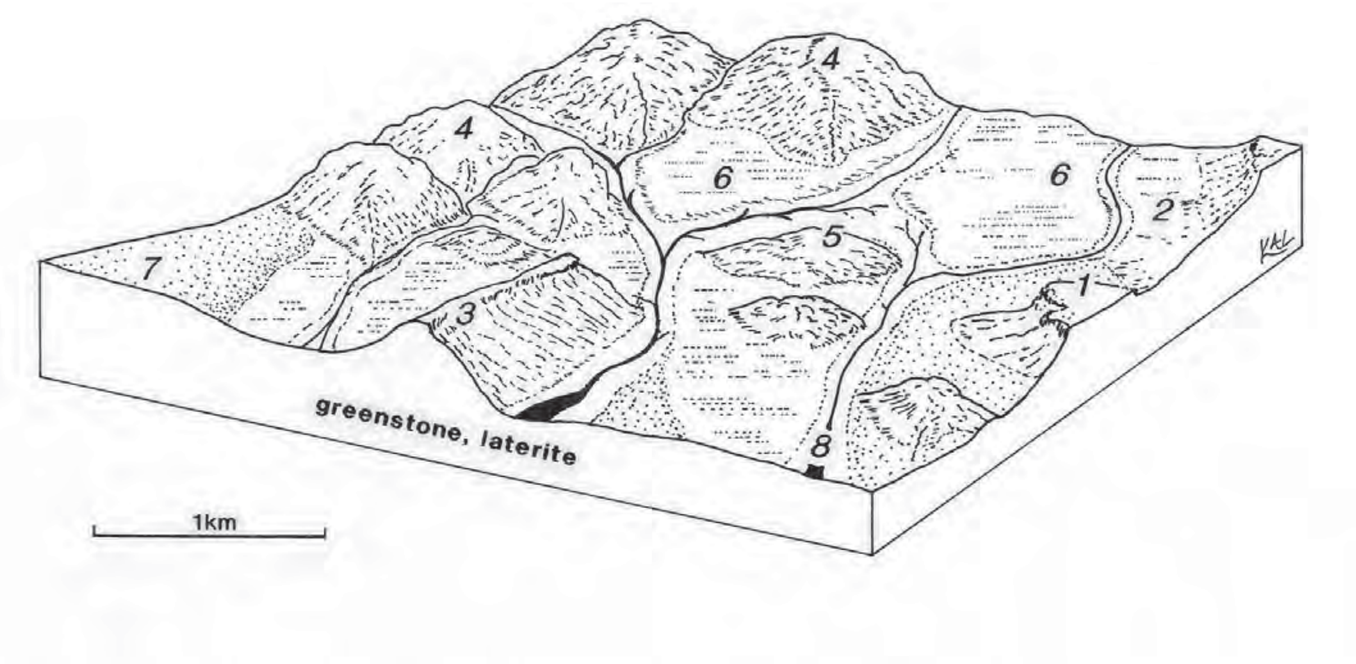
Geomorphology: Erosional surfaces; uplands of dissected limonitic duricrust; irregular low hills and rises capped with limonite, plateaux and small breakaways with short footslopes, extensive lower colluvial slopes, very gently inclined plains with mantles of ferruginous gravel and narrow drainage tracts.

Land management: Minor areas with texture contrast soils on breakaway footslopes (unit 2) and narrow drainage tracts (unit 8) are susceptible to soil erosion, particularly if perennial shrub cover is substantially reduced or the soil surface is disturbed.

Traverse condition summary (16 assessments):
Vegetation – good 44%; fair 25%; poor 19%; very poor 12%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway	1	–
2	Breakaway footslopes	–	–
3	Ridge	–	–
4	Hill and hill slope	2	3
5	Low rise	–	–
6	Stony plain	8	–
7	Lateritic plain	7	–
8	Narrow drainage tract	1	–
	Total	19 *	3

* 3 traverse points not assessed for condition.

Bevon land system

Unit area (%)		Landform	Soil	Vegetation
1.	<1%	**Breakaways** – very gently undulating plateaux with surface duricrust with scarp faces to 5 m and moderately inclined scree slopes, unit relief <20 m.	Stony soils (1).	Scattered to moderately close (10-30% PFC) generally non-saline low shrublands characterised by *Ptilotus obovatus* (cotton bush).
2.	5%	**Breakaway footslopes** – very gently inclined lower slopes to 200 m long, often with a mantle of ferruginous pebbles; on pallid zone materials.	Shallow red clays with a stony mantle or shallow duplex on greenstone (9a, 7b).	Variable scattered to moderately close (10-30% PFC) halophytic low shrublands, occasionally with a tall shrub stratum dominated by *A. aneura* (mulga) and *Eucalyptus* spp. in the south (SAMP, FRAN, SBMS).
3.	<1%	**Ridges** – occasional ridges of banded ironstone to 35 m relief, with gently to moderately inclined slopes.	Stony soils (1).	Very scattered to moderately close (2.5-30% PFC) *A. aneura* tall shrublands (SIMS).
4.	20%	**Hills and hillslopes** – irregular hills to 15 m relief, gently inclined slopes with abundant mantles of limonite pebbles and cobbles.	Shallow red earths and stony soils on greenstone (5c, 1), occasionally calcareous.	Very scattered to moderately close (2.5-30% PFC) *A. aneura* or *A. acuminata* subsp. *burkittii* (fine-leaf jam) tall shrublands (SIMS, SIAS).
5.	15%	**Low rises** – gently undulating rises with mantles of limonite pebbles.	Stony soils (1).	Scattered (10-20% PFC) tall acacia shrublands (SIAS).
6.	40%	**Stony plains** – extensive very gently inclined pediments with mantles of limonitic pebbles and cobbles.	Shallow red earths on greenstone (5c).	Generally scattered (10-20% PFC) *A. aneura* tall shrublands (SIMS, SAES), occasionally scattered low bluebush shrublands (SBMS), or *Eucalyptus lesouefii* (Goldfields blackbutt) woodlands in south on calcareous slopes.
7.	15%	**Lateritic plains** – very gently inclined plains with mantles of ironstone gravel, subject to diffuse sheet flow.	Shallow red earths on greenstone (5c).	Scattered (10-20% PFC) *A. aneura* tall shrublands (LHMS).
8.	5%	**Drainage tracts** – tracts to 400 m wide, generally unchannelled.	Shallow red earths on greenstone (5c).	Moderately close (20-30% PFC) *A. aneura* tall shrublands (DRAS).

BROOKING LAND SYSTEM (366 km², 0.4% of the survey area)

(after Pringle *et al.* 1994)

Prominent ridges of banded iron formation, supporting mulga shrublands.

Land type: 1

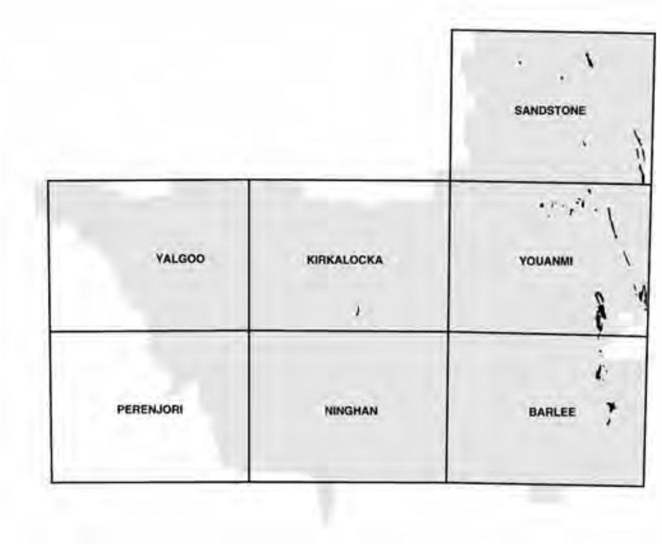
Geology: Archaean banded iron formation, locally quartzite, slate, shale and greywacke, with Quaternary colluvium and minor alluvium.

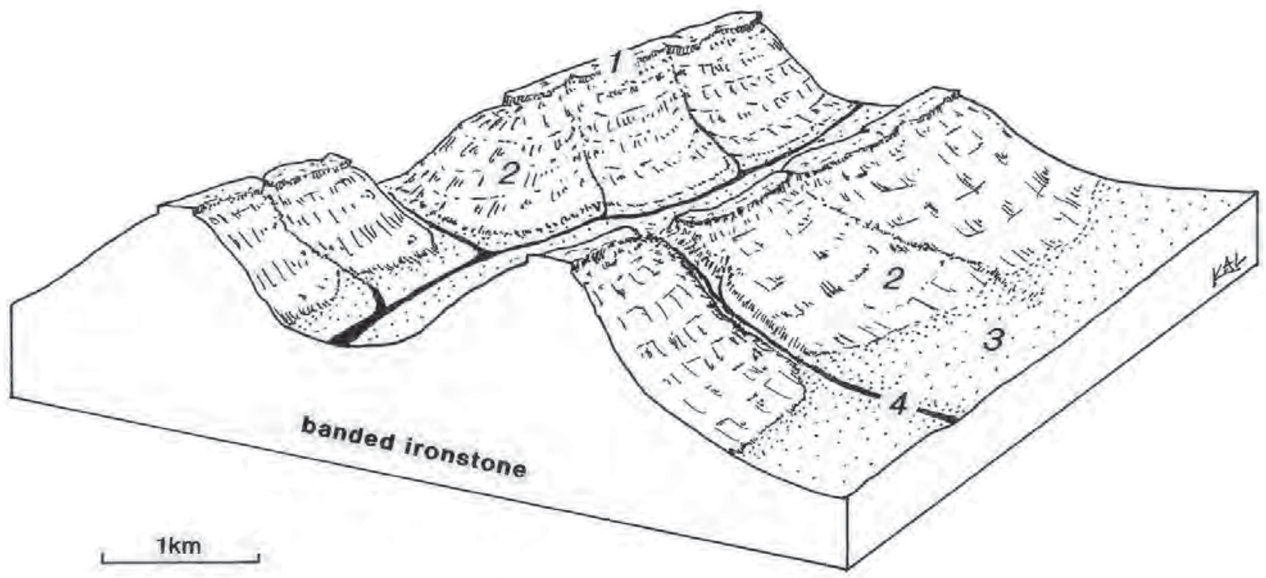
Geomorphology: Erosional surfaces; linear ridges to 8 km long and occasionally greater than 60 m relief, generally much lower; gently inclined slopes with colluvium and sparse, often incised, narrow drainage tracts.

Land management: Stone mantles provide effective protection against soil erosion. Disturbance or removal of mantles may initiate erosion.

Traverse condition summary (31 assessments):
Vegetation – good 65%; fair 3%; poor 26%; very poor 6%
Soil erosion – nil 97%; slight 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Ridge	5	3
2	Hillslope	4	2
3	Stony plain	18	1
4	Narrow drainage tract	5	1
	Total	32	7

* 1 traverse points not assessed for condition.

Brooking land system

Unit area (%)	Landform	Soil	Vegetation
1. 15%	**Ridges** – generally linear ridges of banded iron formation (usually <60 m relief) with moderately inclined short upper slopes, with mantles of abundant angular and platy banded ironstone fragments.	Stony soils or shallow stony red earths (1, 5b).	Scattered to moderately close (10-30% PFC) shrublands dominated either by *Acacia aneura* (mulga) or *A. acuminata* subsp. *burkittii* (fine-leaf jam) tall shrubs or by *Ptilotus obovatus* (cotton bush) low shrubs (SIMS, GHAS).
2. 50%	**Hillslopes** – gently inclined slopes with mantles of abundant angular and platy banded ironstone fragments.	Stony soils or shallow stony red earths (1, 5b).	Scattered (10-20% PFC) *Acacia aneura* tall shrublands (SIMS).
3. 30%	**Stony plains** – very gently to gently inclined plains with mantles of abundant ironstone pebbles.	Shallow red earths and shallow stony red earths (5c, 5b).	Scattered (10-20% PFC) *A. ramulosa* (bowgada) and *A. aneura* tall shrublands (SIMS), rarely with halophytic low shrubs (SBMS).
4. 5%	**Narrow drainage tracts** – linear and narrow (<50 m) drainage zones with shallow channels in higher sectors.	Shallow red earths (5b).	Moderately close (20-30% PFC) *A. aneura* tall shrublands (DRAS).

BULLIMORE LAND SYSTEM (6,249 km², 6.6% of survey area)

(after Mabbutt *et al.* 1963)

Sandplains supporting spinifex hummock grasslands.

Land type: 10

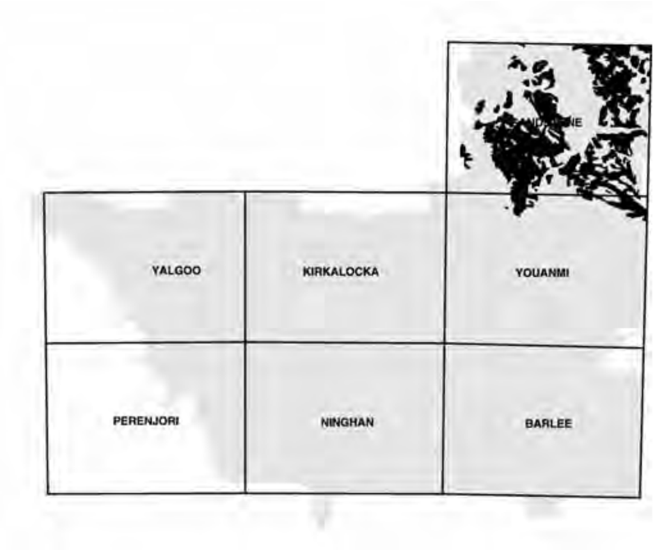
Geology: Sand of Tertiary/Quaternary age, minor siliceous and ferruginous duricrusts, Archaean granite and Quaternary loam alluvium.

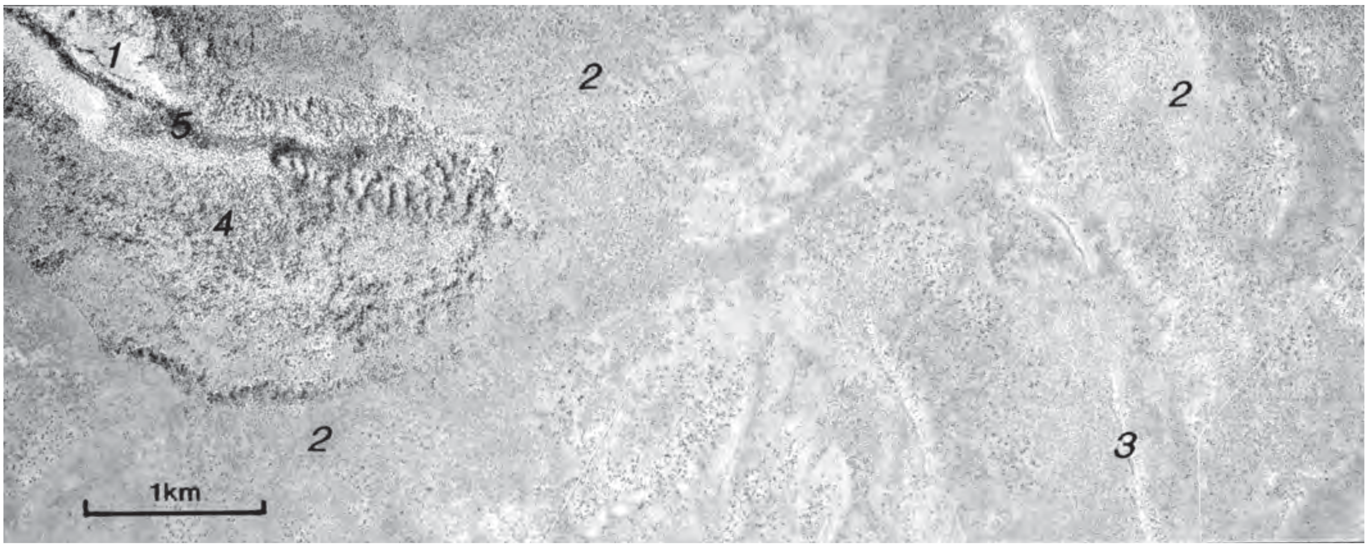
Geomorphology: Depositional surfaces; gently undulating sandplains that have been variously re-worked by aeolian, fluvial and colluvial processes. Minor (often weathered) granite outcrop, frequently with a siliceous (occasionally calcareous) duricrust.

Land management: Spinifex hummock grasslands are highly flammable. Wildfires in hot months with strong winds can cause considerable damage to fences and to adjacent, less fire adapted plant communities. Fire breaks will minimise capital losses and help to localise outbreaks of fire. Wind erosion may occur after fire, however stabilisation is usually rapid following rain and consequent regeneration of vegetation.

Traverse condition summary (231 assessments):
Vegetation – good 89%; fair 3%; poor 7%; very poor; 1%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Dissected tract	1	–
2	Sand sheet	198	7
3	Sand dune	5	2
4	Loamy plain	28	–
5	Narrow drainage tract	3	–
	Other	3	–
	Total	238 *	9

* 7 traverse points not assessed for condition.

Bullimore land system

Unit area (%)		Landform	Soil	Vegetation
1.	2%	**Dissected tracts** – variably stripped weathered granite surfaces; including incipient breakaways.	Shallow coarse red clayey sands (2a).	Very variable; low myrtaceous shrublands (BRXS) sometimes with *A. aneura* (mulga) tall shrubs, or *Casuarina pauper* (black oak) trees in calcareous areas.
2.	85%	**Sand sheet** – extensive level to gently undulating plains, occasionally more than 10 km wide.	Deep red clayey sands (3a).	*Triodia basedowii* (hard spinifex) hummock grasslands with generally very variable scattered tall shrubs and trees (10-20% PFC) (*Acacia* spp., Proteaceae and *Eucalyptus* spp.), often with heath low shrubs (SASP, SAMU).
3.	1%	**Sand dunes** – generally linear, occasionally reticulate, aeolian deposits to 5 km long and generally <10 m high.	Deep red sands (3c).	Very variable; dominated by spinifex, low myrtaceous heath or eucalypts, heath component invariably prominent (SDSH).
4.	10%	**Loamy plains** – generally level tracts to 2 km wide subject to sheet run – on from adjacent outcrops of granite.	Sandy red earths (4).	Scattered to close (10-30% PFC) *Acacia aneura* and *A. ramulosa* (bowgada) shrublands, variably with spinifex and wanderrie grasses (SACS, MUBW).
5.	2%	**Narrow drainage tracts** – narrow (<100 m) tracts subject to concentrated sheet flow and sump areas near granite outcrops.	Sandy red earths (4).	Very variable; close (30-50% PFC), *A. aneura* tall shrublands occasionally with heath shrubs, spinifex or wanderrie grasses (DRAS).

BUNNY LAND SYSTEM (16 km², 0.02% of the survey area)

(after Curry *et al.* 1994)

Hardpan plains with broad sandy banks and thin sand sheets supporting acacia shrublands with wanderrie grasses.

Land type: 14

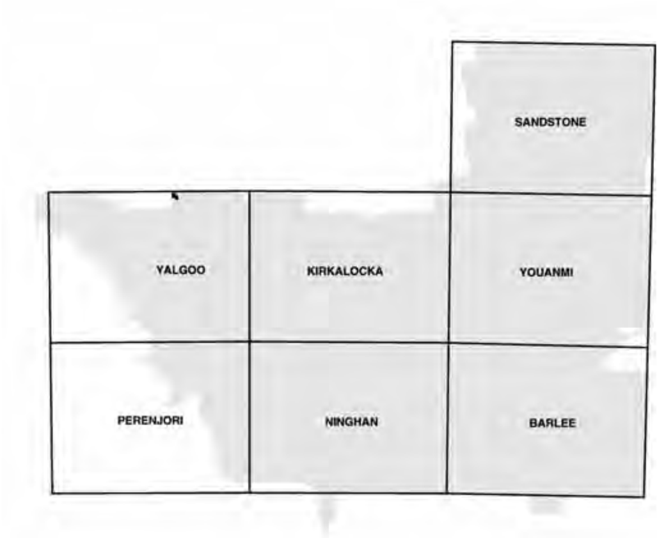
Geology: Quaternary alluvium with cemented alluvium and aeolian sand.

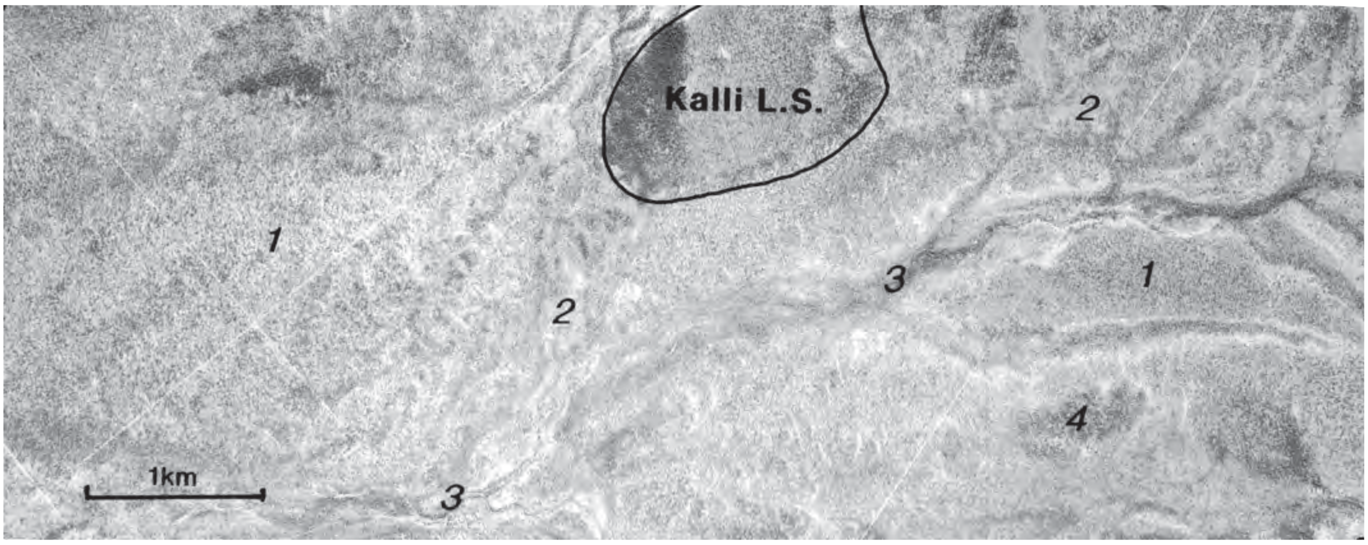
Geomorphology: Depositional surfaces; nearly level alluvial plains on hardpan, subject to diffuse sheet flow between slightly elevated sandy tracts; occasional drainage tracts with narrow channels; isolated, small claypans; relief mostly <5 m.

Land management: This system is not usually susceptible to erosion.

Traverse condition summary: Not traversed.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank / sand sheet	–	–
2	Hardpan plain	–	–
3	Drainage tract	–	–
4	Drainage focus	–	–
	Total	0	0

Bunny land system

Unit area (%)		Landform	Soil	Vegetation
1.	60%	**Sandy banks and sand sheets** – sandy banks and minor, thin sand sheets to 1 km in extent.	Deep and shallow red clayey sands over hardpan (3a, 2d).	Scattered to moderately close (10-30% PFC) mixed shrublands with a wanderrie grass layer (WABS). Wanderrie grasses include *Monachather paradoxa* (broad-leaved wanderrie), *Thyridolepis multiculmis* (soft wanderrie), *Eragrostis eriopoda* (woolly butt) and *Eriachne helmsii* (buck wanderrie).
2.	30%	**Hardpan plains** – nearly level plains, locally with ironstone gravelly mantles.	Shallow hardpan loams and shallow red earths over hardpan (5c, 5b).	Scattered (10-20% PFC) mid shrublands dominated by *Hakea arida* (standback) and *Acacia grasbyi* (miniritchie) (HPMS).
3.	5%	**Drainage tracts** – very gently inclined drainage tracts to 0.5 m wide, but more commonly <200 m wide with braided narrow channels incised in hardpan.	Shallow red clayey sands or shallow red earths over hardpan or weathered granite (2d, 4b, 5c).	Scattered to close (10-30% PFC) *A. acuminata* subsp. *burkittii* (fine -leaf jam) or *A. grasbyi* tall shrublands (HPMS, DRAS).
4.	5%	**Drainage foci** – occasional small depositional zones <200 m in diameter.	Shallow clays over hardpan (9a).	Mostly bare, but where vegetated moderately close (10-30% PFC) *A. tetragonophylla* (curara) tall shrubland (DRAS).

CAMPSITE LAND SYSTEM (173 km^2, 0.2% of the survey area)

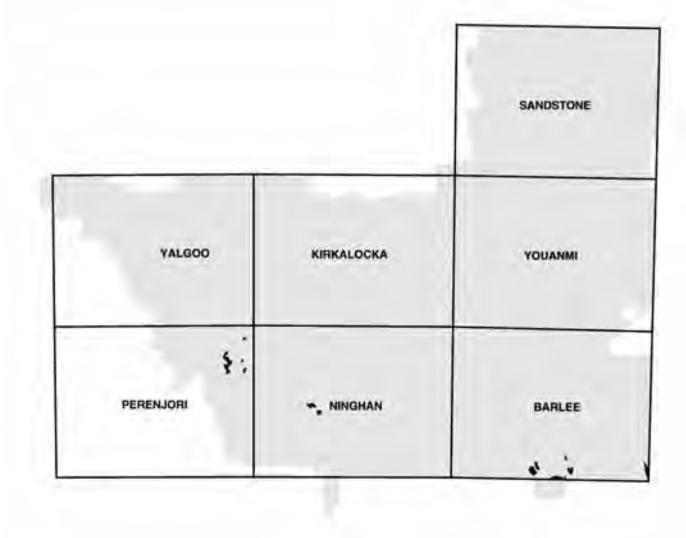
(after Pringle *et al.* 1994)

Alluvial plains supporting eucalypt woodlands with saltbush understoreys and eucalypt-acacia shrublands.

Land type: 17

Geology: Quaternary alluvium and colluvium.

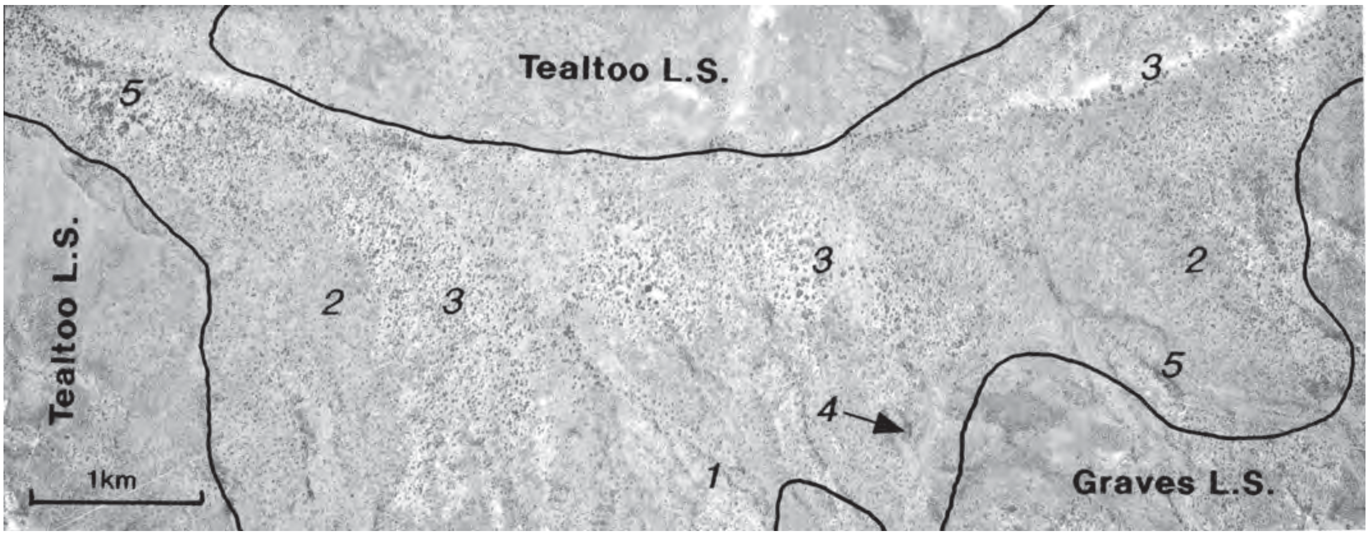
Geomorphology: Depositional surfaces; level to gently undulating plains and unchannelled drainage tracts on alluvium receiving sheet flow; also plains with loamy surfaces receiving more diffuse sheet flow and slightly higher plains with gravel and stone mantles.



Land management: Alluvial plains (unit 3) are slightly susceptible to soil erosion if perennial shrub cover is substantially reduced, as are stony plains (unit 1) if protective stone mantles are disturbed or removed. Impedance to natural drainage characteristics can initiate accelerated soil erosion and cause loss of vigour in vegetation downslope due to water starvation. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate land management, including control of total grazing pressure.

Traverse condition summary (29 assessments):
Vegetation – good 34%; fair 38%; poor 28%; very poor 0%.
Soil erosion – nil 97%; minor 3%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1	Saline stony plain	11	3
2	Loamy plain	10	1
3	Alluvial plain	7	3
4	Grove	–	1
5	Drainage tract	1	1
	Total	29	9

Campsite land system

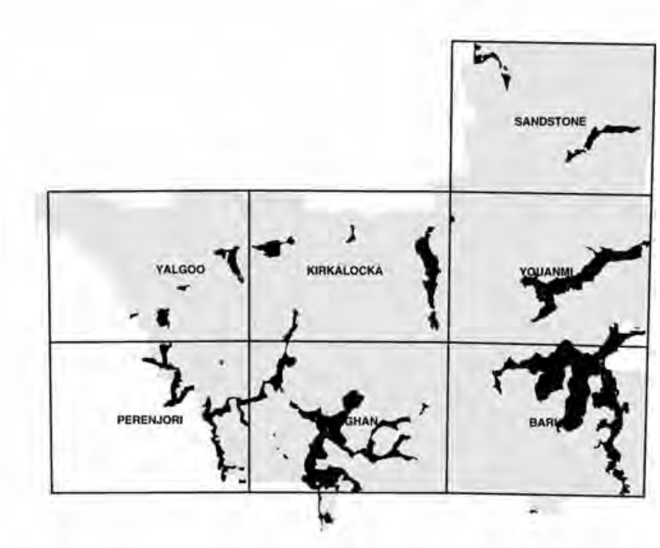
Unit area (%)		Landform	Soil	Vegetation
1.	35%	**Saline stony plains** – nearly level plains with mantles of common to abundant ironstone and quartz gravels.	Deep clays with a stony mantle (9b), occasionally gilgaied or shallow red earths on greenstone (5c).	Scattered to moderately close (10-30% PFC) eucalypt woodlands with *Atriplex vesicaria* (bladder saltbush) understoreys (PECW). *Eucalyptus* species are *E. salubris* (gimlet), *E. salmonophloia* (salmon gum), occasionally *E. loxophleba* (York gum).
2.	33%	**Loamy plains** – level to gently undulating plains on the margins of the system often with mantle of few to many fine ironstone gravels.	Deep red clayey sands or deep red earths (3a, 6a).	Scattered (10-20% PFC) *A. ramulosa* (bowgada) eucalyptus tall shrublands (PYAW).
3.	25%	**Alluvial plains** – level plains receiving flow from greenstone hill systems, weakly groved; may have mixed mantles of few pebbles.	Deep or shallow red earths on hardpan or rock (6a, 5c).	Scattered to moderately close (10-30% PFC) eucalypt woodlands with halophytic understoreys (PECW) or eucalypt-acacia woodlands or tall shrublands (PYAW). Occasionally low halophytic shrublands (BLSS, PSAS).
4.	2%	**Groves** – drainage foci to 100 m in extent on units 1 and 3.	Deep clays (9b).	Close eucalypt woodlands (PECW) or close (30-50% PFC) *Acacia ramulosa* tall shrublands (GRMU).
5.	5%	**Drainage tracts** – central unchannelled drainage tracts receiving concentrated flow.	Shallow hardpan red loams (5d) or shallow to deep red earths on hardpan (5c, 6a).	Moderately close (20-30% PFC) *A. ramulosa* tall shrublands, occasionally with eucalypt overstorey (DRAS).

CARNEGIE LAND SYSTEM (8,649 km², including bare lake bed, 9.1% of survey area)

(after Mabbutt *et al.* 1963)

Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands.

Land type: 10



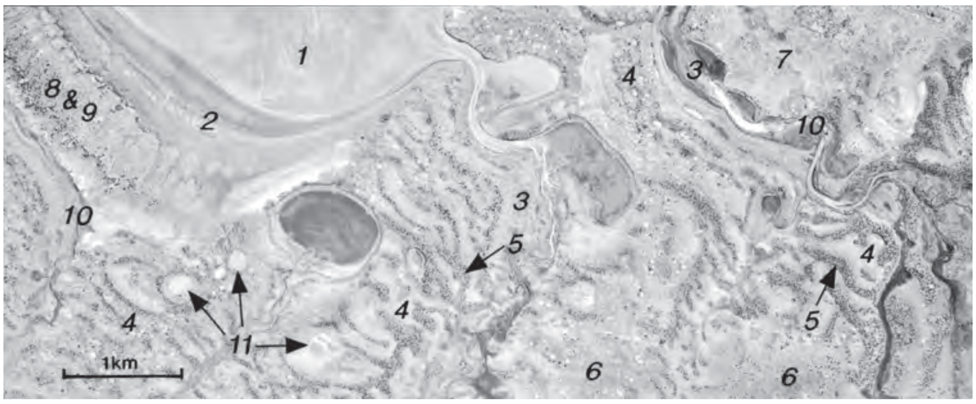
Geology: Quaternary lacustrine saline clay and sand, saline alluvium, aeolian sand and gypsum, minor Tertiary calcrete.

Geomorphology: Depositional surfaces; salt lakes and fringing level to very gently inclined plains with saline alluvium, low sandy banks and sand dunes on surrounding saline plains, undulating kopi dunes and gently undulating plains with calcrete rubble. Nearly level plains subject to sheet flow, with non-saline alluvium, on boundary of system; occasional drainage foci and narrow drainage lines.

Land management: Lack of slope renders most of this system not susceptible to water erosion. Minor areas receiving concentrated run-on in unit 4 are susceptible to rilling when shrub cover is substantially reduced or run-on is accelerated due to increased run-off from degraded areas upslope. Wind erosion of lake margins (unit 2) may be exacerbated by loss of stabilising perennial shrubs. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate land management, including control of total grazing pressure.

Traverse condition summary (567 assessments):
Vegetation – good 62%; fair 27%; poor 9%; very poor 2%.
Soil erosion – nil 93%; slight 3%; minor 2%; moderate 1%; severe 1%.

Area mapped as sde: 3.7 km² (<0.1% of land system's area).



No.	Unit name	Traverse recordings	Inventory sites
1	Lake bed	2	–
2	Lake margin	20	2
3	Saline plain	66	2
4	Alluvial plain	231	18
5	Sandy bank	128	11
6	Hardpan plain	69	3
7	Calcrete plain	21	–
8	Kopi dune	15	3
9	Dune	–	–
10	Drainage line	6	1
11	Drainage foci	14	3
	Other	6	–
	Total	578 *	43

* 11 traverse points not assessed for condition.

Carnegie land system

Unit	area (%)	Landform	Soil	Vegetation
1.	30%	**Lake beds** – lake floors.	Highly saline (11).	Unvegetated.
2.	5%	**Lake margins** – hummocky plains marginal to unit 1.	Deep red clayey sands (3a) or gypsiferous sediments.	Scattered (10-20% PFC) *Atriplex vesicaria* (bladder saltbush) low shrublands (BLSS), or *Halosarcia* spp. (samphire) (SAMP).
3.	8%	**Saline plains** – level to gently undulating highly saline lower plains and drainage zones.	Deep clays (9b) or gypsiferous sediments.	Scattered to moderately close (10-30% PFC) low shrublands, usually *Halosarcia* spp. but also *Frankenia* spp. (frankenia) (SAMP, FRAN).
4.	30%	**Alluvial plains** – level to gently undulating saline plains, marginally higher than unit 3.	Shallow duplex on hardpan or occasionally calcrete (7c).	Scattered (10-20% PFC) halophytic low shrublands (PXHS), may be dominated by *Atriplex vesicaria* (bladder saltbush) (BLSS) or by *A. bunburyana* (silver saltbush) (SSAS); scattered (10-20% PFC) *Acacia masliniana* (spiny snakewood) with halophytic undershrubs (ASWS); occasionally scattered (10-20% PFC) *Eucalyptus loxophleba* (York gum) woodlands with halophytic undershrubs (PYCW).
5.	12%	**Sandy banks** – level to gently undulating low rises up to 4 m above the surrounding plains, and level sandy tracts. sands (3a).	Shallow red clayey sands on hardpan (2d) or deep red clayey	Scattered to moderately close (10-30% PFC) acacia tall shrublands. Dominant species include *Acacia ramulosa* (bowgada), *A. acuminata* subsp. *burkittii* (fine-leaf jam), *A. grasbyi* (miniritchie) and *A. masliniana* or low halophytic shrublands with acacia tall shrubs. Common low shrubs include *A. bunburyana* and *Gunniopsis quadrifida* (sweet samphire), occasionally with a spinifex hummock grass layer (SBLS).
6.	8%	**Hardpan plains** – nearly level plains on the margins of the system, receiving sheet flow.	Red clayey sands on hardpan at variable depth (2d, 3a).	Scattered (10-20% PFC) low shrublands with a mixture of halophytic and non-halophytic shrubs and *Acacia aneura* (mulga) tall shrubs (HMCS, HPMS).
7.	3%	**Calcrete plains** – gently undulating plains with calcrete rubble mantles.	Shallow calcareous loams on calcrete (5a).	Variable scattered (10-20% PFC) shrublands with *Acacia* spp. and halophytic and non-halophytic low shrubs.
8.	1%	**Kopi dunes** – low dunes with gently undulating crests to 1.5 km long and about 200 m wide; with 1-8 m relief, above unit 3 and in unit 1.	Encrusted gypsiferous sediments with shallow red sand in pockets (11).	Very scattered to scattered (2. 5-20% PFC) *Eucalyptus striaticalyx* (kopi gum) woodlands with mixed shrub understorey or very scattered *Melaleuca sheathiana* (boree) tall shrublands (KOPI).
9.	1%	**Dunes** – generally linear, aeolian deposits to 10 m high fringing lake beds.	Deep red sands (3c).	Scattered (10-20% PFC) mixed shrublands occasionally with a eucalypt overstorey and dense spinifex grass layer.
10.	1%	**Drainage lines** – narrow drainage lines receiving concentrated flow, occasional small channels.	Deep red earths or deep clays (6a, 9b).	Moderately close (20-30% PFC) acacia tall shrublands occasionally with halophytic undershrubs (DACS). Halophytic low shrublands near lake beds (PXHS, SAMP).
11.	1%	**Drainage foci** – small circular depressions, swamps and claypans.	Deep red earths or deep clays (6a, 9).	Moderately close to close (20-50% PFC) tall shrubland (PDFT) in depressions; close (30-50% PFC) melaleuca shrublands (MESS) in swamps; claypans are unvegetated.

CHALLENGE LAND SYSTEM (3,655 km², 3.9% of survey area)

(after Curry *et al.* 1994)

Gently undulating gritty-surfaced plains, occasional granite hills, tors and low breakaways, with acacia shrublands.

Land type: 6

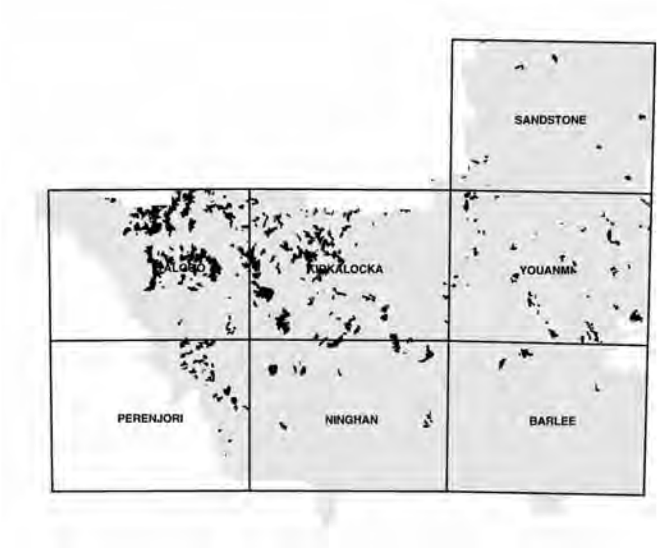
Geology: Archaean granite

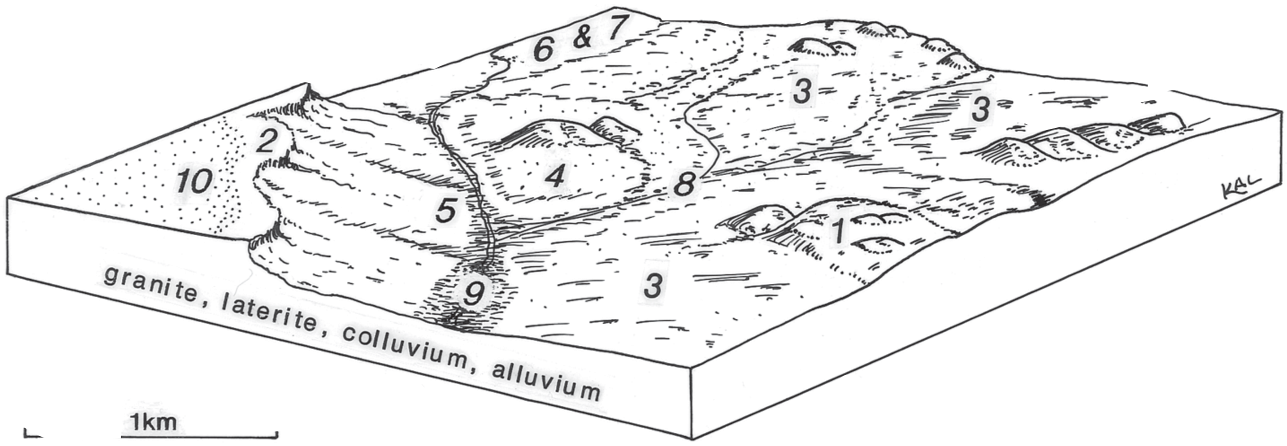
Geomorphology: Mainly erosional surfaces; very gently undulating gritty-surfaced plains with sandy drainage zones, minor plains with stone mantles and occasional hills, tors and low breakaways, generally with less than 10 m relief but occasionally up to 25 m.

Land management: Saline stony plains (unit 5) and alluvial plains (unit 9) are moderately susceptible to water erosion.

Traverse condition summary (448 assessments):
Vegetation – good 31%; fair 42%; poor 22%; very poor 5%.
Soil erosion – nil 96%; slight 2%; moderate 1%; severe 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Granite tor/dome	1	0
2	Breakaway	19	1
3	Gritty-surfaced plain	164	9
4	Stony plain	59	2
5	Saline stony plain	24	1
6	Loamy plains	37	–
7	Hardpan plain	79	3
8	Drainage line	35	2
9	Alluvial plain	21	3
10	Sand sheet	19	1
	Total	458 *	22

* 10 traverse points not assessed for condition.

Challenge land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Granite tors and domes** – granite tors and domes generally <10 m relief with much bare rock.	Restricted pockets of shallow coarse red clayey sands (2a).	Very scattered to scattered (2.5-20% PFC) *Acacia quadrimarginea* (granite wattle) tall shrublands (GRHS).
2.	2%	**Breakaways** – low breakaways up to 25 m relief, with short saline footslopes.	Restricted pockets of shallow coarse red clayey sands (2a).	Scattered (10-20% PFC) mixed shrublands on breakaways and footslopes (BRXS, BCLS).
3.	38%	**Gritty-surfaced plains** – level to gently undulating plains with abundant fine quartz gravel and coarse sand, minor or common granite outcrop.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) mixed shrublands with *Acacia aneura* (mulga) or *A. quadrimarginea* tall shrubs (SGRS, GABS).
4.	15%	**Stony plains** – gently undulating plains with few to common quartz and granite pebbles and cobbles on the surface and minor granite outcrop.	Shallow coarse red clayey sands with a stony mantle (2a), or shallow red clayey sands on granite (2d).	Scattered (10-20% PFC) acacia-eremophila shrublands. Dominant acacias include *A. quadrimarginea*, *A. acuminata* subsp. *burkittii* (fine-leaf jam) and *A. tetragonophylla* (curara) (SAES, SGRS).
5.	5%	**Stony saline plains** – level to gently undulating plains with many quartz pebbles and cobbles.	Shallow red earths on granite (5c).	Scattered (10-20% PFC) low shrublands commonly dominated by *Maireana pyramidata* (sago bush) (SBMS).
6.	5%	**Loamy plains** – level plains.	Red clayey sands (2d, 3a) or sandy red earths on hardpan at variable depth (4).	Scattered to moderately close (10-30% PFC) *A. aneura, A. ramulosa* (bowgada) tall shrublands with occasional wanderrie grasses (MUBW, PLMS).
7.	12%	**Hardpan plains** – level to gently undulating plains based on hardpan, may have a quartz pebble mantle.	Shallow red earths (5c) or shallow hardpan loams on hardpan, occasionally with a stony mantle (5d).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (HPMS, HCAS). Dominant acacias include *A. ramulosa, A. acuminata* subsp. *burkittii* and *A. grasbyi* (miniritchie).
8.	5%	**Drainage lines** – narrow drainage floors with some channels.	Shallow red clayey sands (2d) or shallow duplex on granite (7a).	Moderately close (20-30% PFC) acacia tall shrublands (DRAS).
9.	5%	**Alluvial plains** – level plains receiving run-on from higher units.	Shallow duplex on granite (7a).	Scattered (10-20% PFC) halophytic low shrublands which may be dominated by *Maireana pyramidata* (PSAS). Also PXHS, ASWS.
10.	3%	**Sand sheets** – gently undulating sand sheet.	Shallow red clayey sands with ferruginous gravel on laterite (2b).	Moderately close (20-30% PFC) acacia tall shrublands (SACS).

COSMO LAND SYSTEM (50 km², 0.05% of the survey area)

(after Pringle *et al.* 1994)

Calcreted drainage axes through sandplain with spinifex hummock grasslands and occasional black oak or mulga open woodlands.

Land type: 18

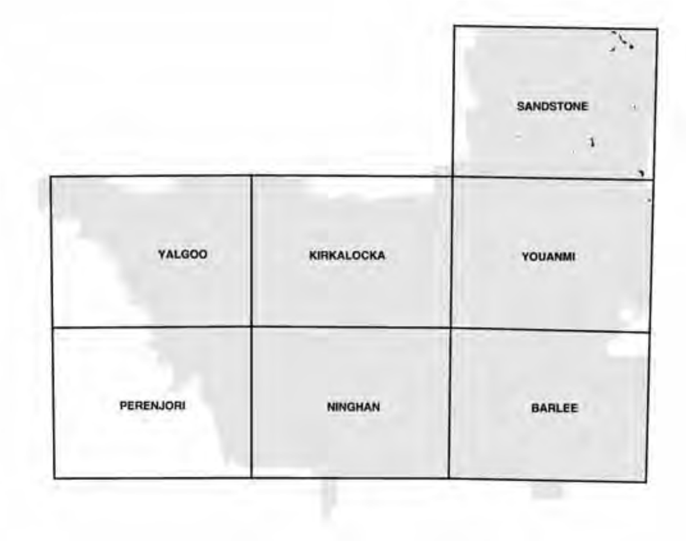
Geology: Tertiary calcrete, Quaternary aeolian sand and minor alluvium.

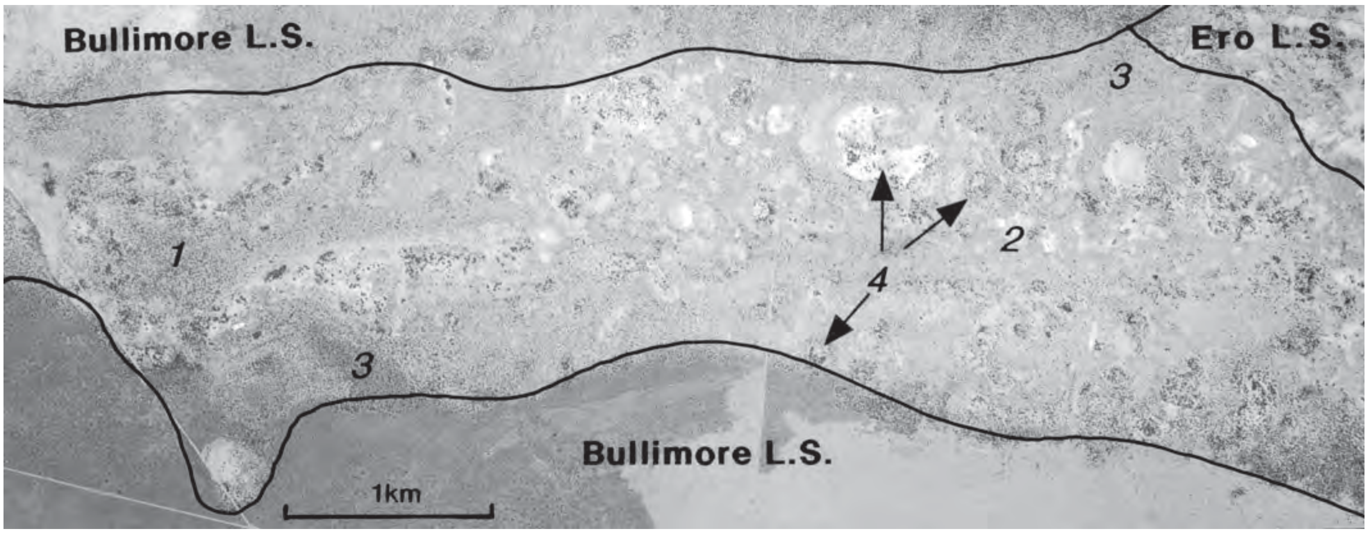
Geomorphology: Depositional surfaces; gently undulating calcrete platforms (<1 m relief) level to very gently inclined plains with calcrete rubble, sandy sheets marginal to spinifex sandplain (Bullimore land system), and occasional drainage foci.

Land management: Spinifex hummock grasslands are susceptible to fire and following fire sands on unit 3 may become susceptible to wind erosion until regrowth occurs following rains.

Traverse condition summary (10 assessments):
Vegetation – good 60%; fair 20%; poor 10%; very poor 10%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Calcrete platform	1	–
2	Calcrete plain	1	–
3	Sand sheet	6	–
4	Drainage focus	2	1
	Total	10 *	1

* 4 traverse points not assessed for condition.

Cosmo land system

Unit area (%)		Landform	Soil	Vegetation
1.	40%	**Calcrete platforms** – gently undulating low rises with 1 m relief, calcrete rubble and calcrete outcrop.	Shallow red clayey sands on calcrete (2c).	Scattered (10-20% PFC) *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) tall shrublands (JAMS).
2.	25%	**Calcrete plains** – level to gently undulating plains with calcrete rubble and calcrete outcrop.	Shallow red clayey sands on calcrete (2c).	Scattered (10-20% PFC) *A. acuminata* subsp. *burkittii* tall shrublands (JAMS).
3.	30%	**Sand sheets** – level sandplain partially covering units 1 and 2.	Deep red clayey sands, or shallow red clayey sands on calcrete (3a, 2c).	*Triodia basedowii* (hard spinifex) hummock grasslands (SASP).
4.	5%	**Drainage foci** – slight depressions receiving run-on.	Shallow hardpan loams (5d).	Closed (> 50% PFC) melaleuca shrublands with *Melaleuca uncinata* and *M. sheathiana* (boree) or moderately close (20-30% PFC) acacia tall shrublands (MESS, DRAS).

CUNYU LAND SYSTEM (358 km², 0.4% of the survey area)

(after Mabbutt *et al.* 1963)

Calcrete platforms and intervening drainage floors and minor areas of alluvial plains, with acacia shrublands, casuarina woodlands and minor halophytic shrublands.

Land type: 18

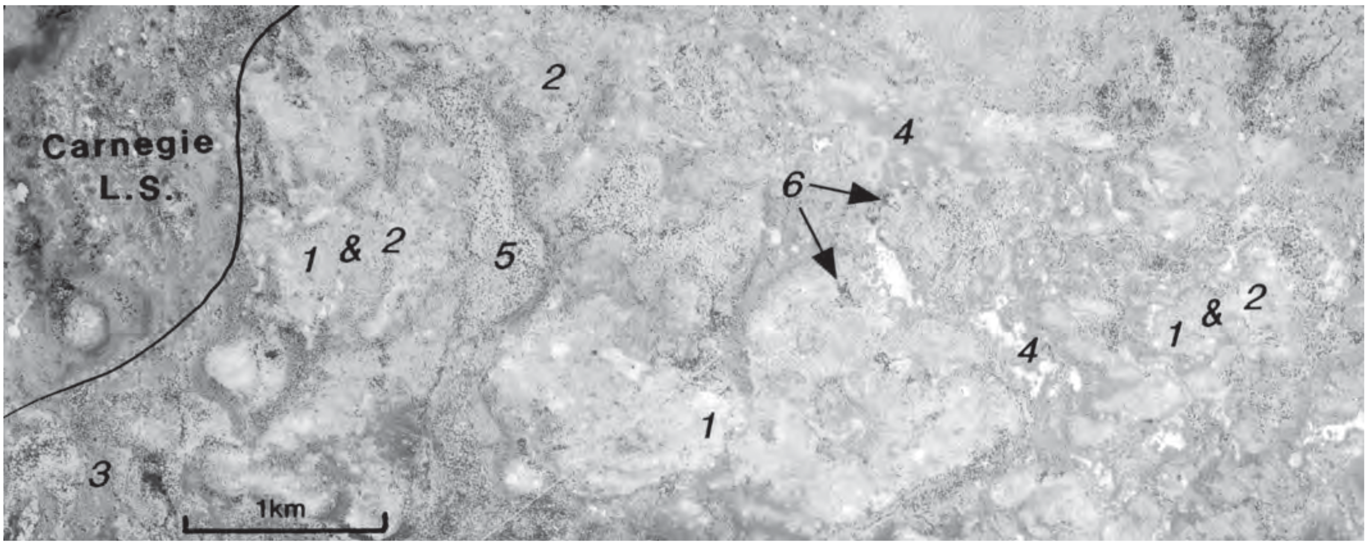
Geology: Tertiary calcrete and Quaternary alluvium.

Geomorphology: Depositional surfaces, calcreted valley fill; calcrete platforms and intervening drainage floors and broader alluvial plains, also minor plains with mantles of calcrete rubble and occasional drainage foci.

Land management: Alluvial plains (unit 4) and drainage floors (unit 5) are moderately susceptible to water erosion if perennial shrub cover is substantially reduced or the soil surface is disturbed. Seasonal production of annual herbs and grasses is high in this land system. These plants are highly attractive to a wide range of herbivores and land managers should aim to control total grazing pressure in these preferred pastures.

Traverse condition summary (85 assessments):
Vegetation – good 13%; fair 17%; poor 42%; very poor 28%.
Soil erosion – nil 87%; slight 1%; minor 9%; moderate 1%; severe 1%; extreme 1%.

Area mapped as sde: 3.6 km² (1.0% of land system's area).



No.	Unit name	Traverse recordings	Inventory sites
1	Calcrete platform	42	7
2	Calcrete plain	16	–
3	Hardpan plain	7	2
4	Alluvial plain	11	–
5	Drainage floor	3	1
6	Drainage foci	11	4
	Other	6	–
	Total	96 *	14

* 11 traverse points not assessed for condition.

Cunyu land system

Unit area (%)		Landform	Soil	Vegetation
1.	48%	**Calcrete platforms** – very gently inclined platforms (to 4 m relief), with calcrete rubble and outcrop.	Shallow red clayey sands or shallow calcareous loams, on calcrete (2c, 5a).	Scattered (10-20% PFC) *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) and other acacia grassy tall shrublands (JAMS) or very scattered (2.5-10% PFC) *Casuarina pauper* (black oak) woodlands with *Senna artemisioides* subsp. *petiolaris* (desert cassia) and *Ptilotus obovatus* (cotton bush) as common low shrubs (CAPW).
2.	25%	**Calcrete plains** – level plains with mantles of calcrete pebbles.	Shallow calcareous loams or shallow red clayey sands, on calcrete (5a, 2c).	Scattered to moderately close (10-30% PFC) *Acacia acuminata* subsp. *burkittii* tall shrublands (JAMS).
3.	10%	**Hardpan plains** – nearly level plains subject to weak sheet flow.	Shallow red clayey sands on hardpan or shallow hardpan loams (2d, 5c).	Moderately close (20-30% PFC) acacia tall shrublands (HCAS). Dominant acacias are *A. acuminata* subsp. *burkittii, A. grasbyi* (miniritchie), *A. tetragonophylla* (curara) and *A. aneura* (mulga).
4.	10%	**Alluvial plains** – nearly level plains marginally lower than units 1 and 2, subject to unchannelled through drainage.	Shallow duplex on hardpan and deep duplex (7c, 8).	Scattered to moderately close (10-30% PFC) halophytic low shrublands occasionally with *Acacia eremaea* (snakewood) tall shrubs (PXHS, ASWS).
5.	5%	**Drainage floors** – mostly unchannelled drainage tracts. (<250 m wide) between units 1 & 2.	Shallow red clays (9a), or shallow red earths on hardpan (5c).	Moderately close (20-30% PFC) acacia or acacia-melaleuca tall shrublands (DRAS).
6.	2%	**Drainage foci** – foci to 400 m in diameter but usually much less, collecting run-off from surrounding plains.	Shallow clays on calcrete or hardpan and deep clays (9a, 9b).	Scattered to moderately close (10-30% PFC) tall shrublands of *A. aneura* or *Melaleuca sheathiana* (boree) with a mixture of halophytic and non-halophytic mid and low shrubs and patchy perennial grasses (MESS, PDFT) or tussock grasslands of *Eragrostis setifolia* (neverfail) or *Eriachne flaccida* (claypan grass) with *Acacia tetragonophylla* tall shrubs (ACGU).

DEADMAN LAND SYSTEM (214 km^2, 0.2% of the survey area)

(after Pringle *et al.* 1994)

Calcareous plains adjacent to salt lake systems, supporting acacia shrublands with black oak overstoreys.

Land type: 19

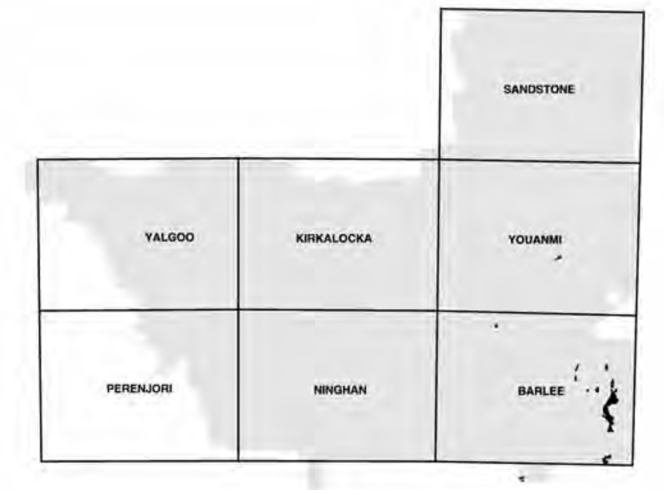
Geology: Quaternary alluvium, some Tertiary calcrete.

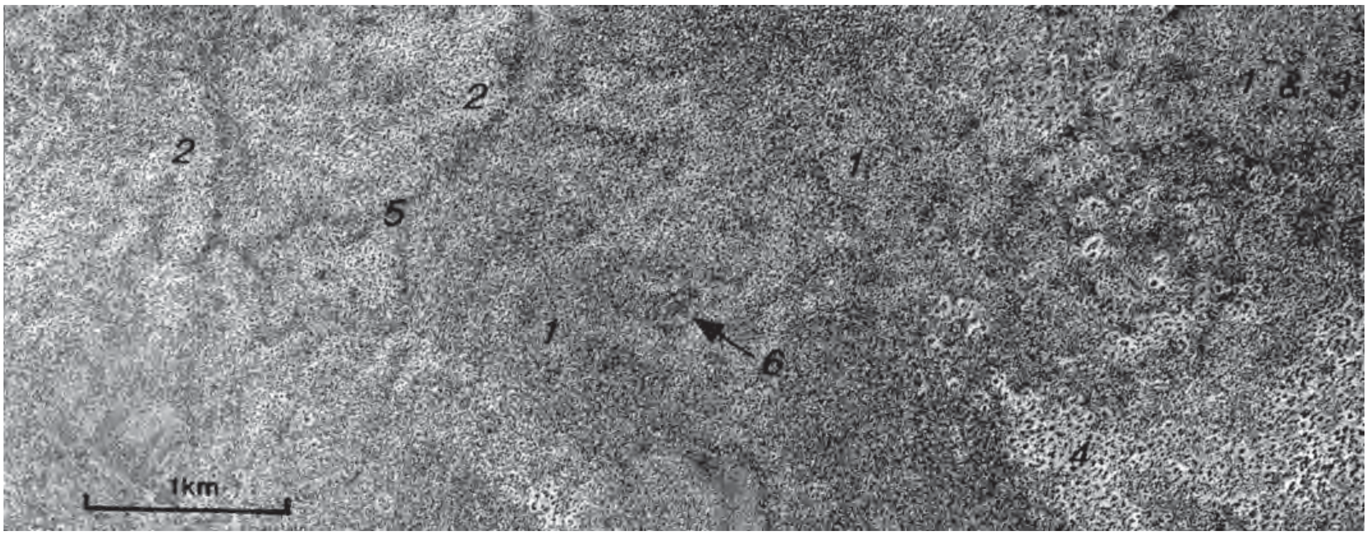
Geomorphology: Depositional surfaces; level to gently undulating plains with little defined drainage apart from sparse, broad unchannelled tracts and occasional drainage foci, minor areas of sandplain.

Land management: This land system is generally not susceptible to soil erosion.

Traverse condition summary (36 assessments):
Vegetation – good 78%; fair 11%; poor 11%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Loamy plain	26	2
2	Calcrete plain	9	2
3	Sand sheet	–	–
4	Alluvial plain	2	–
5	Drainage line	–	1
6	Drainage focus	–	–
	Other	2	–
	Total	39 *	5

* 3 traverse points not assessed for condition.

Deadman land system

Unit area (%)		Landform	Soil	Vegetation
1.	60%	**Loamy plains –** extensive level to gently undulating plains.	Deep calcareous red earths, deep red earths or shallow red clayey sands, on calcrete (6b, 6a, 2d).	Moderately close (20-30% PFC) *Casuarina pauper* (black oak) woodlands or acacia tall shrublands with occasional *C. pauper* (CCAS).
2.	27%	**Calcrete plains –** level plains based on calcrete, may have patchy mantles of calcrete rubble.	Shallow calcareous loams or sandy red earths, on calcrete (5a, 4).	Scattered (10-20% PFC) *A. ramulosa* (bowgada) or *A. acuminata* subsp. *burkittii* (fine-leaf jam) shrublands with *Casuarina pauper* overstorey (CCAS).
3.	5%	**Sand sheets –** gently undulating plains.	Deep red clayey sands (2a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (SACS).
4.	5%	**Alluvial plains –** level plains in lowest areas adjacent to salt lakes.	Deep duplex (8).	Scattered (10-20% PFC) eucalypt woodlands with *Atriplex* spp. (saltbush) undershrubs (PECW).
5.	2%	**Drainage lines –** occasional narrow unchannelled drainage tracts.	Deep calcareous red earths and shallow hardpan loams (6b, 5d).	Moderately close to close (20-50% PFC) acacia shrublands with *Casuarina pauper* overstorey (CCAS)
6.	1%	**Drainage foci –** occasional small foci.	Deep red earths on calcrete (6a).	Moderately close (20-30% PFC) acacia-casuarina shrublands (CCAS).

DESDEMONA LAND SYSTEM (40 km^2, 0.04% of survey area)

(after Pringle *et al.* 1994)

Plains with deep sandy or loamy soils, supporting mulga and wanderrie grasses.

Land type: 16

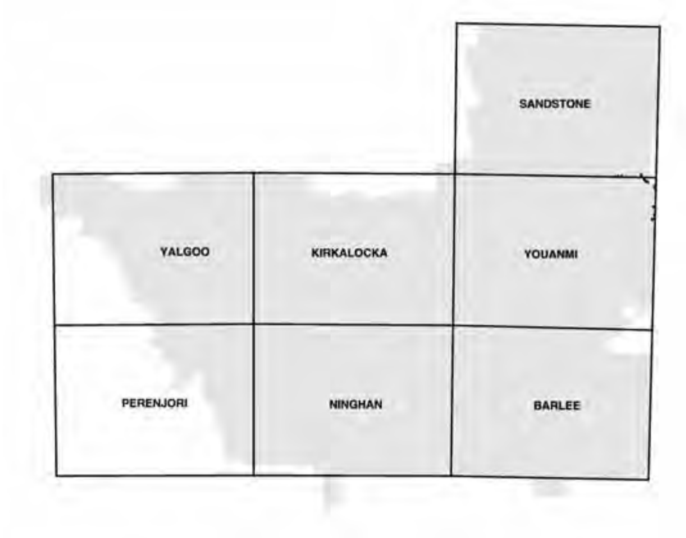
Geology: Quaternary sand and loam with minor cemented alluvium; derived mainly from granitic rocks.

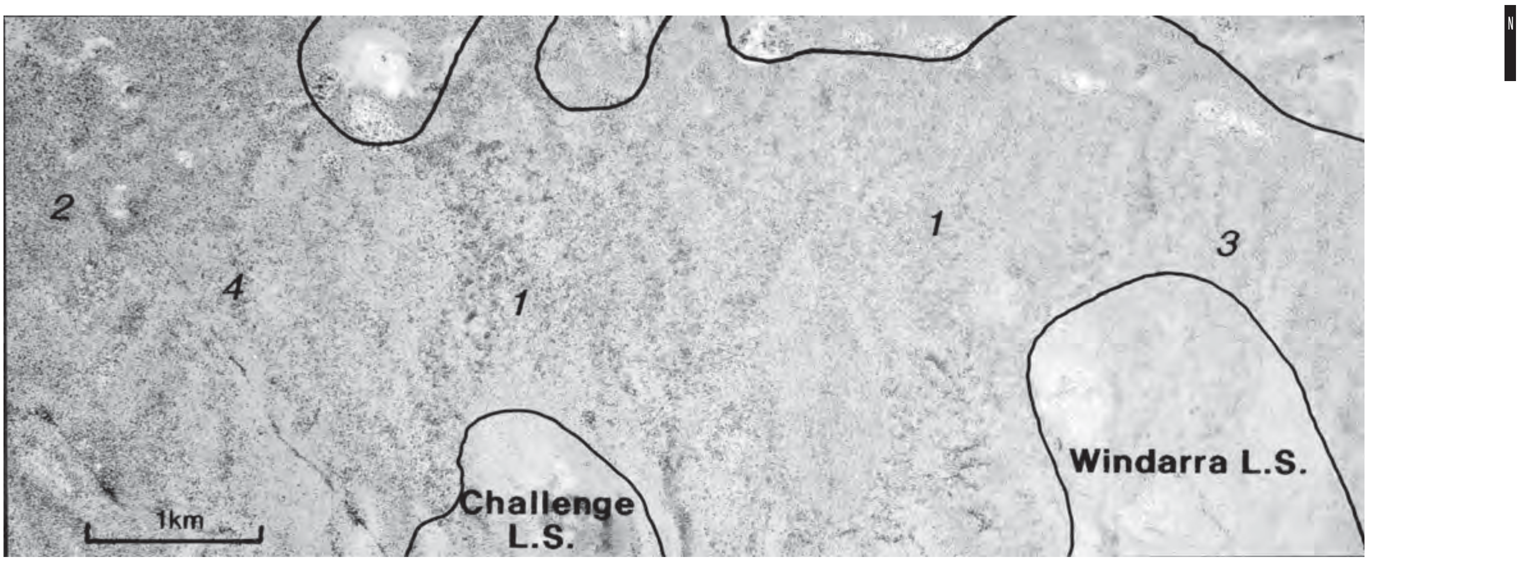
Geomorphology: Depositional surfaces; generally level plains receiving very dispersed or no run-on; frequently flanked by extensive areas with more active drainage.

Land management: Lack of slope, relatively dense vegetation and very diffuse nature of sheet flow renders this system generally not susceptible to soil erosion.

Traverse condition summary (3 assessments):
Vegetation – insufficient assessments.
Soil erosion – insufficient assessments.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Loamy plain	3	–
2	Sand sheet	–	–
3	Hardpan plain	–	–
4	Narrow drainage zone	–	–
	Total	3	0

Desdemona land system

Unit	area (%)	Landform	Soil	Vegetation
1.	80%	**Loamy plains** – level plains subject to very diffuse run-on.	Deep red clayey sands or deep red earths (3a, 6a).	Scattered to moderately close (10-30% PFC) *Acacia aneura* (mulga) tall shrubs with wanderrie grasses (MUWA).
2.	10%	**Sand sheets** – generally level plains without surface drainage features.	Deep red clayey sands (3a).	Scattered (10-20% PFC) Acacia tall shrublands with wanderrie, *Amphipogon caricinus* (grey beard grass) and hummock grasses, and occasional heath shrubs (SACS, MUWA).
3.	7%	**Hardpan plains** – level to very gently inclined plains subject to sheet flow.	Shallow red earths on hardpan (5c).	Scattered (10-20% PFC) tall *A. aneura* shrublands (HPMS).
4.	3%	**Narrow drainage zones** – infrequent poorly defined zones receiving concentrated run-on, <200 m wide.	Sandy red earths (4).	Scattered to close (10-50% PFC) *A. aneura* tall shrublands (HPMS, DRAS).

DONEY LAND SYSTEM (1,287 km^2, 1.4% of the survey area)

(after Pringle *et al.* 1994)

Alluvial plains with eucalypt woodlands.

Land type: 19

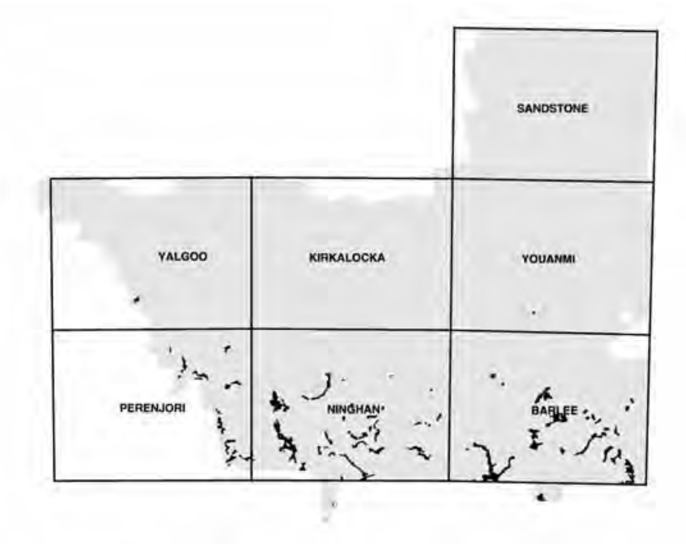
Geology: Quaternary alluvium and minor sand.

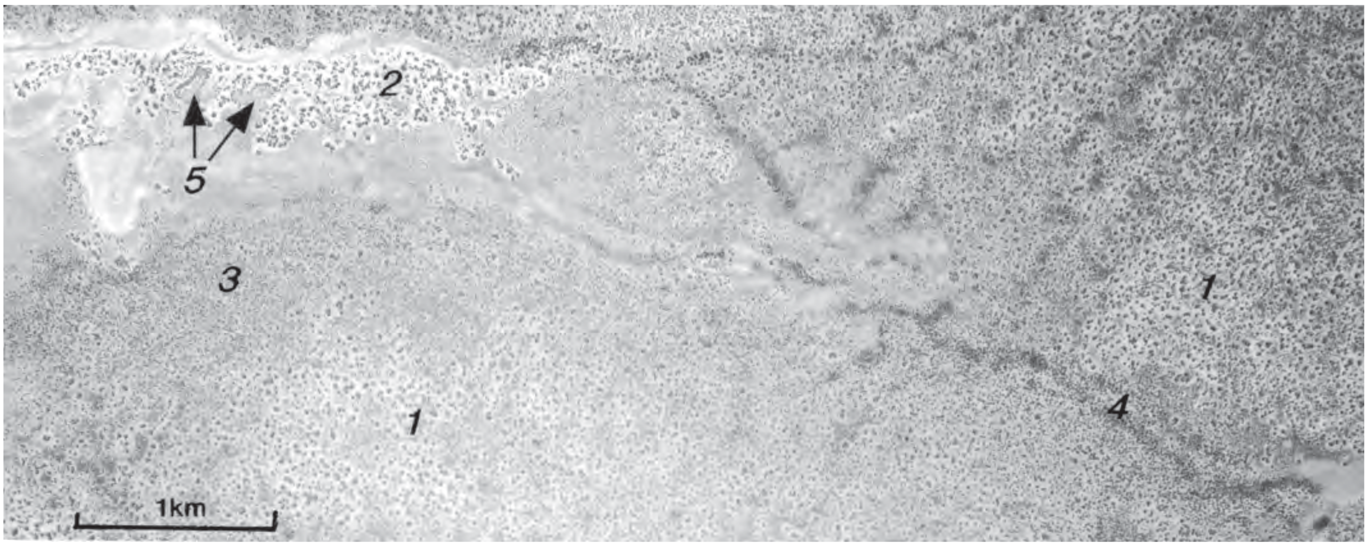
Geomorphology: Depositional surfaces; nearly level plains receiving diffuse sheet flow; minor sparse unchannelled drainage lines, drainage foci, lower tracts with saline alluvium and sand sheets.

Land management: This land system is generally not susceptible to soil erosion.

Traverse condition summary (133 assessments):
Vegetation – good 50%; fair 34%; poor 14%; very poor 2%
Soil erosion – nil 98%; minor 1%; moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Loamy plain	102	12
2	Alluvial plain	20	6
3	Sand sheet	10	1
4	Drainage line	1	1
5	Drainage focus	2	–
	Total	135 *	20

* 3 traverse points not assessed for condition.

Doney land system

Unit area (%)		Landform	Soil	Vegetation
1.	75%	**Loamy plains** – nearly level plains subject to diffuse sheet flow.	Shallow red earths, red clayey sands and hardpan loams (5c, 2d, 5d).	Scattered to moderately close (10-30% PFC) eucalypt woodlands, usually with *Eucalyptus loxophleba* (York gum), with tall acacia shrubs. Common undershrubs include *Senna artemisioides* subsp. *petiolaris* (desert cassia), *Eremophila ionantha, E. scoparia* (broom bush), *Olearia muelleri* (Goldfields daisy), (PYAW,). Also moderately close (20-30% PFC) *Callitris glaucophylla* (native pine) woodland with acacia tall shrubs (PINW).
2.	15%	**Alluvial plains** – level plains, occasionally with gilgai micro-relief.	Deep or shallow calcareous red earths and loams on calcrete (6b, 5a), cracking clays on gilgai areas (10).	Scattered to moderately close (10-30% PFC) eucalypt woodlands with *Atriplex stipitata* (bitter saltbush) low shrubs. Eucalypt species are *E. loxophleba, E. salmonophloia* (salmon gum) and *E. salubris* (gimlet), (PYCW, PECW).
3.	6%	**Sand sheets** – level sandplain marginally higher than units 1 and 2.	Deep red clayey sands (3a).	Moderately close (20-30% PFC) acacia tall shrublands with mallee eucalypts (MAAS, SACS).
4.	3%	**Drainage lines** – meandering unchannelled drainage tracts.	Deep calcareous red earths (6b).	Close (30-50% PFC) acacia tall shrublands with mixed undershrubs (DRAS). Also eucalypt woodlands with halophytic undershrubs (PECW).
5.	1%	**Drainage foci** – occasional rounded foci mostly less than 500 m in extent but occasionally larger.	Sandy red earths (4).	Moderately close (20-30% PFC) tall *Acacia aneura* (mulga) shrublands (DRAS) or unvegetated.

DRYANDRA LAND SYSTEM (353 km^2, 0.4% of the survey area)

Ridges of banded iron formation supporting dense mixed shrublands with emergent native pines, mallees and casuarinas.

Land type: 2

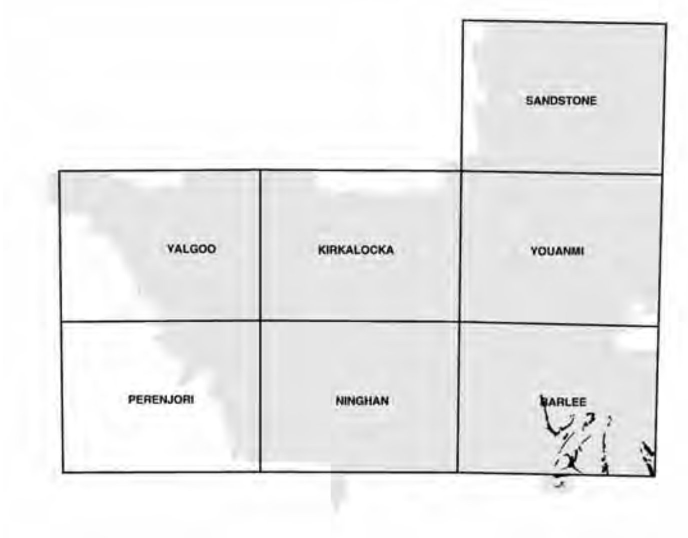
Geology: Archaean magnetite-quartz banded iron formation

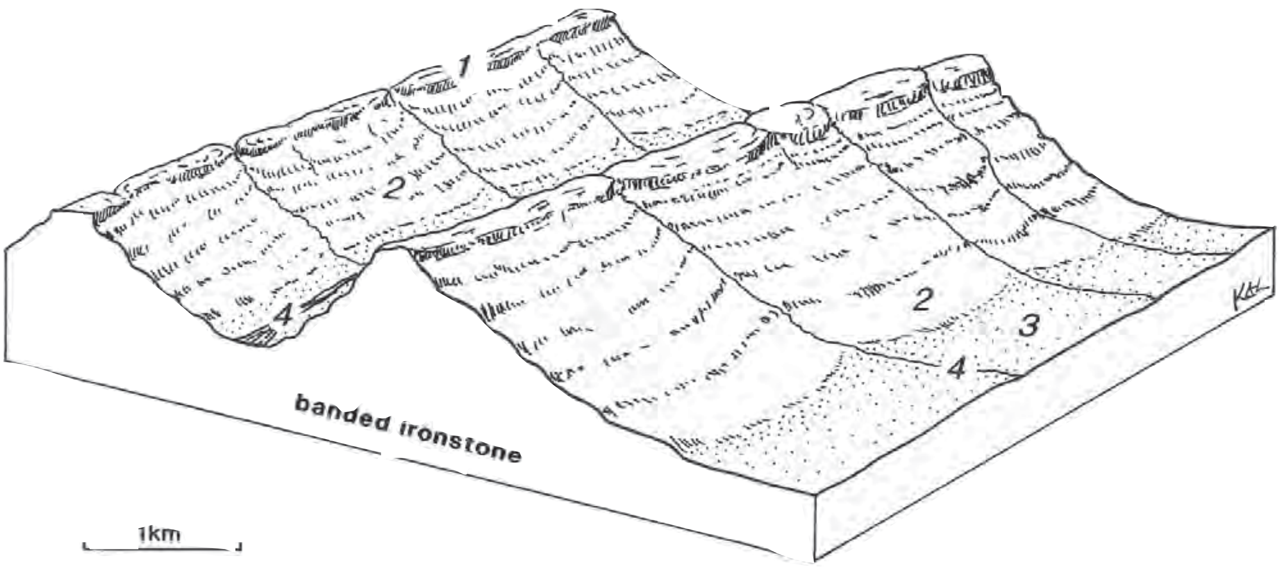
Geomorphology: Erosional surfaces; ridges on banded iron formation with up to 140 m relief, with moderately inclined to steep slopes and gently inclined lower plains.

Land management: Stone mantles protect the soil surface from erosion.

Traverse condition summary (27 assessments):
Vegetation – good 81%; fair 15%; poor 4%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Ridge	5	2
2	Hillslope	5	3
3	Stony plain	10	1
4	Narrow drainage line	13	–
	Total	33	6

* 6 traverse points not assessed for condition.

Dryandra land system

Unit area (%)		Landform	Soil	Vegetation
1.	15%	**Ridges** – linear ridges of banded ironstone formation, up to 140 m relief, with mantles of abundant rock fragments and exposed bedrock.	Stony soils and shallow red clayey sands (1, 2d).	Moderately close to close (20-50% PFC) acacia tall shrublands with emergent *Dryandra arborea* or *Callitris glaucophylla* (native pine) trees (GHAS, GHMW).
2.	50%	**Hillslopes** – moderately or gently inclined slopes of banded ironstone ridges, with mantles of abundant pebbles and cobbles and minor outcrop of banded ironstone.	Stony soils (1).	Moderately close (20-30% PFC) *Acacia ramulosa* (bowgada) shrubland with emergent *C. glaucophylla* trees or grevillea-acacia mid and tall shrubland with *Eriachne aristidea* (false wanderrie) grass layer and heath undershrubs (SIAS, GHMW).
3.	30%	**Stony plains** – undulating plains with mantles of abundant ironstone pebbles.	Shallow red clayey sands with ferruginous gravel (2b).	Moderately close (20-30% PFC) acacia tall shrubland with isolated mallees (*Eucalyptus clelandii*) and *Allocasuarina acuaria*. Acacias include *A. ramulosa, A. aneura* (mulga) and *A. tetragonophylla* (curara) (SIAS).
4.	5%	**Narrow drainage lines** – linear valley tracts between ridges and hills, minor channels.	Shallow red earths (5c).	Moderately close (20-30% PFC) acacia tall shrublands and isolated eucalypts (DRAS).

ERO LAND SYSTEM (531 km^2, 0.6% of the survey area)

(after Mabbutt *et al.* 1963)

Tributary floodplains supporting acacia tall shrublands and halophytic low shrublands.

Land type: 17

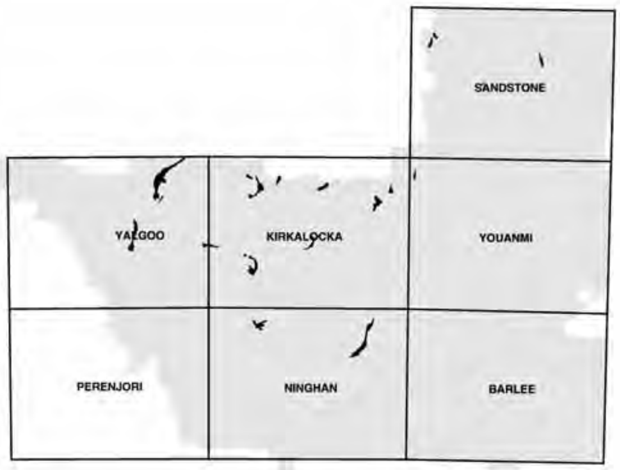
Geology: Quaternary alluvium, partly cemented.

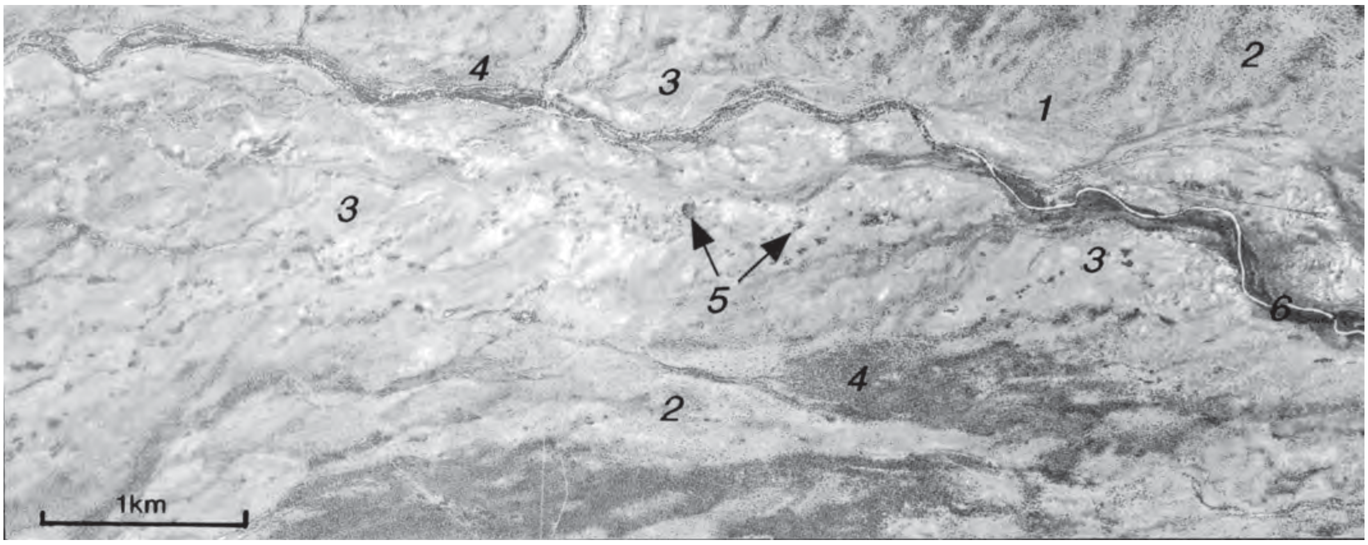
Geomorphology: Depositional surfaces; very gently inclined tributary plains with central concentrated drainage tracts with saline alluvium and minor anastomosing channels, flanked by plains with non-saline alluvium subject to sheet flow; occasional drainage foci.

Land management: The system supports vegetation which is attractive to stock and other animals and is liable to preferential overgrazing. Alluvial plains and drainage tracts (units 3 & 4) are highly susceptible to soil erosion if shrub cover is depleted and are subject to flooding.

Traverse condition summary (138 assessments):
Vegetation – good 31%; fair 36%; poor 21%; very poor 12%.
Soil erosion – nil 58%; slight 15%; minor 10%; moderate 12%; severe 4%; extreme 1%.

Area mapped as sde: 39.9 km^2 (7.5% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank	–	–
2	Hardpan plain	37	2
3	Alluvial plain	75	9
4	Drainage tract	21	4
5	Drainage focus	1	4
6	Channel	5	3
	Total	139	22

* 1 traverse point not assessed for condition.

Ero land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Sandy banks** – to 300 m in extent and up to 1 m above adjacent unit 2.	Deep or shallow red clayey sands over hardpan (3a, 2d).	Very scattered to moderately close (2.5-30% PFC) acacia tall shrublands with *Eremophila* spp. low shrubs and wanderrie grasses (WABS).
2.	20%	**Hardpan plains** – level plains occasionally with a very sparse mantle of pebbles and cobbles, subject to sheet flow.	Shallow loams and red clayey sands over hardpan (5d, 2d). Some duplexes and red earths over hardpan (7c, 5c).	Scattered (10-20% PFC) tall shrublands dominated by *Acacia aneura* (mulga), *A. tetragonophylla* (curara), or *A. grasbyi* (miniritchie) (HPMS, HMCS).
3.	60%	**Alluvial plains** – level to very gently inclined saline plains to 4 km wide, subject to sheet flow and commonly with scalded and eroded surfaces.	Shallow duplex on hardpan (7c), shallow hardpan loams and deep duplex soils (5d, 8).	Very scattered to scattered (2.5-20% PFC) low halophytic shrublands, may be dominated by *Atriplex bunburyana* (silver saltbush) or *Maireana pyramidata* (sago bush) (SSAS, PSAS) occasionally with sparse acacia tall shrubs, commonly *A. eremaea* (snakewood) (ASWS).
4.	10%	**Drainage tracts** – level or gently inclined central tracts to 1 km wide through unit 3 and receiving more regular flooding than unit 3, occasional incised central channels.	Shallow clays, red earths (9a, 5c) or duplexes over hardpan at variable depth (7c, 8).	Scattered to close (10-50% PFC) tall shrublands of *A. tetragonophylla* and *A. aneura* with halophytic and non-halophytic undershrubs (DMCS, HMCS, DRAS).
5.	3%	**Drainage foci** – seasonally flooded claypans, swamps and rounded drainage foci to 400 m in diameter (usually smaller) occurring on units 3 & 4).	Shallow clays, red earths and duplex soils over hardpan or calcreted pans (9, 5c, 7c).	Moderately close to close (20-50% PFC) tall shrublands dominated by *A. tetragonophylla* or *Melaleuca uncinata,* occasionally with patchy grasses (ACGU, DRAS, MESS).
6.	<2%	**Channels** – anastomosing channels up to 25 m wide incised to 2 m deep with hardpan and calcrete exposures.	Channel bedloads of coarse sand, grit and hardpan fragments. Soils on banks are juvenile types of variable depth (12).	Variable fringing woodlands or tall shrublands with *Casuarina obesa* (swamp oak) or *Acacia* spp. and *Callistemon phoeniceus* (lesser bottlebrush) often with halophytic under shrubs (CBKW, CBBS).

EUCHRE LAND SYSTEM (1,769 km², 1.9% of the survey area)

Low granite breakaways with alluvial plains and sandy tracts supporting eucalypt woodlands and acacia shrublands.

Land type: 4

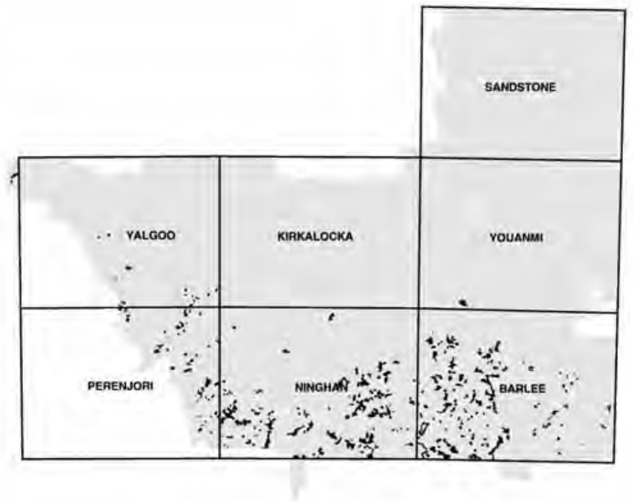
Geology: Weathered and unweathered Archaean granite and adamellite and Quaternary alluvium and sand.

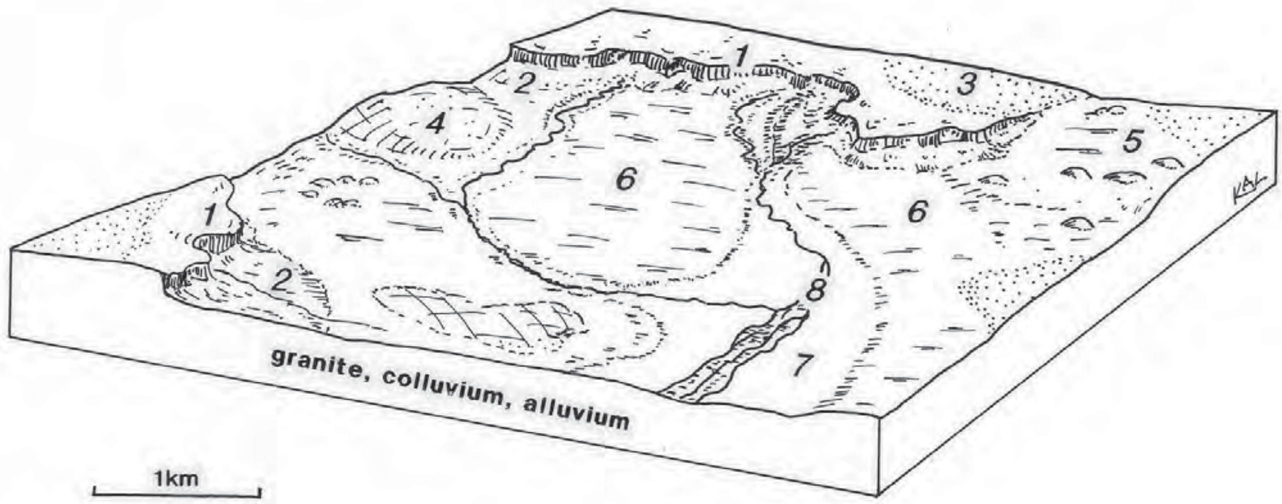
Geomorphology: Erosional and depositional surfaces; low breakaways on granite with up to 10 m relief and restricted very gently inclined footslopes; gently inclined plains on granite with gritty surfaces, lower alluvial plains and sandy tracts.

Land management: Lower footslopes (unit 2) generally have soils which are highly susceptible to water erosion; alluvial plains and drainage floors (units 7 and 8) are moderately susceptible. The vegetation on these units is preferentially grazed by introduced and native animals and is susceptible to overgrazing and consequent degradation. These areas require particularly careful management to avoid land degradation.

Traverse condition summary (188 assessments):
Vegetation – good 72%; fair 22%; poor 4%; very poor 2%.
Soil erosion – nil 99%; slight 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway	20	6
2	Lower footslope	13	9
3	Sandplain, gravelly sandplain	32	–
4	Stony plain	25	1
5	Gritty-surfaced plain	20	2
6	Loamy plain	63	4
7	Alluvial plain	19	5
8	Drainage line	3	3
	Other	3	–
	Total	198 *	30

* 10 traverse points not assessed for condition.

Euchre land system

Unit area (%)	Landform	Soil	Vegetation
1. 10%	**Breakaways** – low breakaways on granite (<10 m relief); variably stripped plateaux, moderately inclined to steep escarpments and short pallid zone upper footslopes.	Very shallow coarse red clayey sands on granite (2a) on plateaux; stony soils or shallow duplex on granite on upper footslopes (1, 7a).	Very scattered to scattered (2.5-20% PFC) mixed low shrubland. Dominant low shrubs include *Thryptomene, Eriostemon* and *Mirbelia* spp. (BRXS) on plateaux; very scattered (2.5-10% PFC) low shrublands on upper footslopes.
2. 15%	**Lower footslopes** – very gently inclined short (up to 400 m wide) lower footslopes below unit 1.	Shallow duplex or shallow red earths on granite (7a, 5c).	Scattered (10-20% PFC) *Eucalyptus loxophleba* (York gum) woodland with low halophytic understoreys (BECW) and scattered (10-20% PFC) low halophytic shrublands occasionally dominated by *Atriplex vesicaria* (bladder saltbush) (BCLS).
3. 15%	**Sandplains/gravelly sandplains** – level plains occasionally with mantles of gravel.	Deep red or yellow clayey sands on gravel (3a, 3b).	Moderately close (20-30% PFC) acacia tall shrublands (SACS, PLMS).
4. 10%	**Stony plains** – very gently inclined plains with mantles of quartz and granite pebbles and cobbles.	Shallow red clayey sands on granite (2d).	Very variable, moderately close (20-30% PFC) tall shrublands with acacias, *E. loxophleba* and halophytic and non-halophytic undershrubs (SAES, PESW, UFTH).
5. 10%	**Gritty-surfaced plains** – gently inclined plains with mantles of quartz and granite small pebbles and coarse sand, and with granite outcrop.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) *Acacia quadrimarginea* (granite wattle) tall shrubland (SGRS).
6. 28%	**Loamy plains** – level plains receiving diffuse run-on.	Shallow red earths or shallow red clayey sands on hardpan (5c, 2d) or deep red earths (6a).	Scattered to moderately close (10-20% PFC) eucalypt woodland with acacia tall shrubs and *Amphipogon* spp. or *Monachather paradoxa* (broad-leaved wanderrie) perennial grasses (PYAW).
7. 10%	**Alluvial plains** – level plains (sometimes with stony mantles) receiving more concentrated flow; occasionally with minor areas of gilgai microrelief.	Shallow duplex or red earths on granite (7a, 5c), or deep duplex (8).	Scattered to moderately close (10-0% PFC) eucalypt woodland with 3 halophytic undershrubs (PECW), sometimes with *Atriplex* spp. dominant.
8. 2%	**Drainage lines** – generally unchannelled drainage zones.	Shallow duplex on granite (5a) and shallow red clayey sands (1d).	Very variable vegetation, some have moderately close (20-30% PFC) *E. loxophleba* woodland with *Atriplex* undershrubs (PECW).

FELIX LAND SYSTEM (112 km^2, 0.1% of the survey area)

(after Pringle *et al.* 1994)

Gently undulating plains with quartz mantles, supporting acacia-eremophila shrublands.

Land type: 9

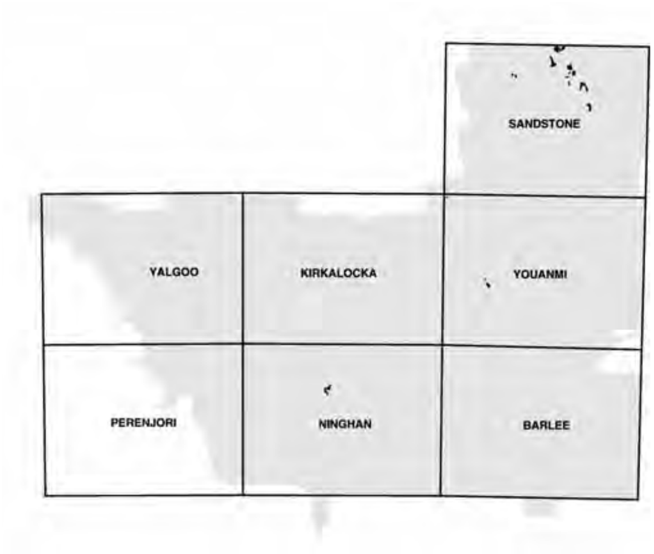
Geology: Quaternary colluvium, alluvium, and eluvium on felsic volcanic rock.

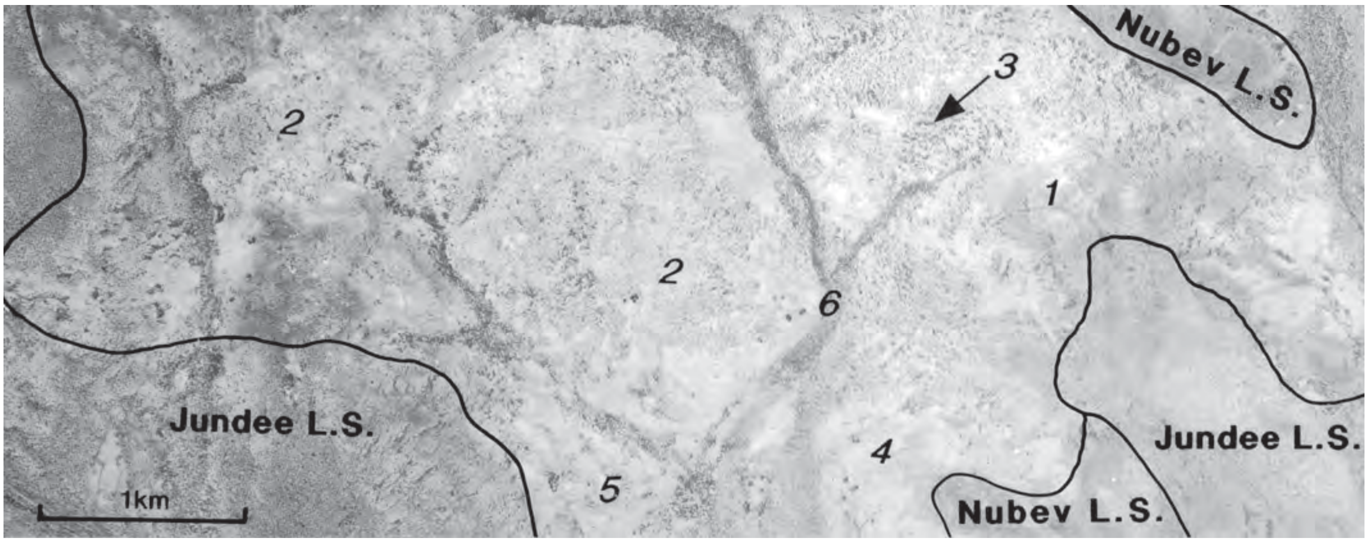
Geomorphology: Erosional surfaces; level to gently undulating plains with quartz and ironstone pebbles and occasional depositional zones; sparse narrow drainage lines; relief <10 m.

Land management: Stone mantles provide effective protection of the soil against erosion.

Traverse condition summary (16 assessments):
Vegetation – good 63%; fair 19%; poor 12%; very poor 6%.
Soil erosion – nil 100%.

Area mapped as sde: 0.1 km^2 (0.08% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Low rise	–	–
2	Stony plain	13	2
3	Grove	–	1
4	Saline stony plain	3	–
5	Loamy plains	3	–
6	Narrow drainage line	–	–
	Total	19 *	3

* 3 traverse records not assessed for condition.

Felix land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Low rises** – occasional low rises with limonite, to 10 m relief.	Shallow red clayey sands with ferruginous gravel (2b).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tallshrublands (SIMS).
2.	60%	**Stony plains** – level to gently undulating plains with mantles of quartz and ironstone pebbles.	Shallow red earths on felsic volcanic rock or on hardpan (5c).	Scattered to moderately close (10-30% PFC) *A. aneura* – eremophila tall shrublands (SAES).
3.	<1%	**Groves** – small drainage foci on unit 2.	Deep red earths (6a).	Moderately close (20-30% PFC) *A. aneura* tall shrubland (GRMU).
4.	10%	**Saline stony plains** – level to gently undulating plains with mantles of quartz and ironstone pebbles.	Shallow duplex or red earths on hardpan (7c, 5c).	Scattered to moderately close (10-30% PFC) shrublands of *Acacia* and *Maireana* spp. (SBMS).
5.	10%	**Loamy plains** – very gently inclined to level plains locally with mantles of quartz pebbles.	Shallow red earths on felsic volcanic rock or hardpan (5c).	Very scattered to scattered (2.5-20% PFC) *A. aneura* tall shrublands or *Eremophila gilesii* (turkey bush) low shrublands; sometimes with wanderrie grasses (HPMS).
6.	15%	**Narrow drainage lines** – generally level zones to 150 m wide receiving concentrated run-on.	Deep red earths (6a).	Moderately close (20-30% PFC) *A. aneura* tall shrublands (DRAS).

GABANINTHA LAND SYSTEM (1,145 km², 1.2% of survey)

(after Mabbutt *et al.* 1963)

Greenstone ridges and hills supporting sparse acacia shrublands.

Land type: 1

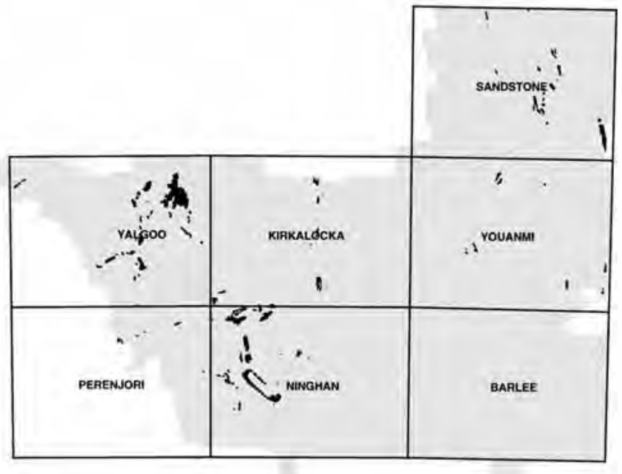
Geology: Metamorphosed Archaean volcanic and sedimentary rocks; basaltic intrusives, felsic volcanics and jaspilite/banded ironstone; Quaternary colluvium; also minor residual material from former Tertiary laterite cappings.

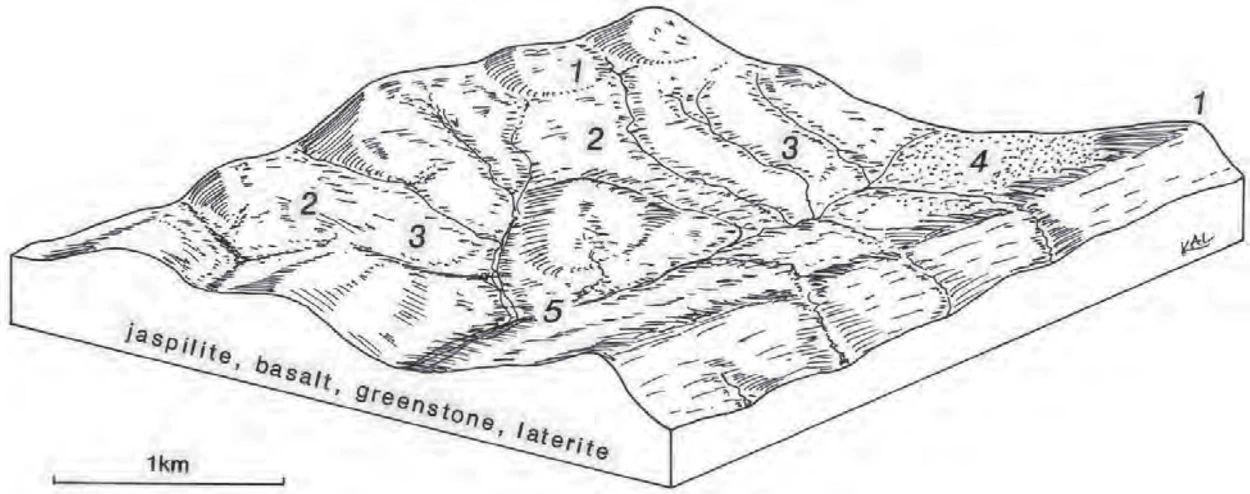
Geomorphology: Erosional surfaces; ranges of low hills and ridges with extensive outcrops of jaspilite and other parent rocks; rounded crests (to 120 m) and concave footslopes with incised more or less rectangular drainage; level to gently undulating plains with stone mantles, grading into alluvial plains with fine ironstone gravel on lower sectors.

Land management: Stone mantles afford protection against soil erosion, the exception being narrow drainage tracts (unit 5) which are mildly susceptible to water erosion. The system is locally affected by mining activity.

Traverse condition summary (102 assessments):
Vegetation – good 32%; fair 54%; poor 9%; very poor 5%.
Soil erosion – nil 98%; slight 1%; minor 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hillcrest, ridge, hill spur	5	6
2	Hillslope	25	9
3	Stony plain	36	3
4	Gravelly plain	12	–
5	Drainage tract	19	3
	Other	7	–
	Total	104 *	21

* 2 traverse points not assessed for condition.

Gabanintha land system

Unit area (%)		Landform	Soil	Vegetation
1.	30%	**Hillcrests, ridges and hill spurs** – rough greenstone crests, spurs and ridges to 120 m; slopes variable up to 15%; mantles of abundant greenstone, dolerite, basalt or schist pebbles and cobbles, frequent rock outcrop.	Stony soils and shallow stony red earths (1, 5b).	Very scattered to scattered (2.5-20% PFC) tall shrublands of *Acacia quadrimarginea* (granite wattle) or *A. aneura* (mulga); *Ptilotus obovatus* (cotton bush) is a common undershrub (SIMS, SIAS).
2.	45%	**Hillslopes** – concave upper slopes to 20%, more gently inclined lower slopes 6% to 1% grading into lower stony plains (unit 3), mantles of abundant greenstone, dolerite, ironstone and other pebbles and cobbles.	Stony soils and shallow duplex on greenstone (1, 7b).	Very scattered to moderately close (2.5-30% PFC) tall shrublands of *A. quadrimarginea* or *A. ramulosa* (bowgada) with sparse undershrubs (GHAS, SIAS).
3.	15%	**Stony plains** – level to gently undulating plains with mantles of common to abundant greenstone or basalt pebbles.	Shallow loams over hardpan or weathered rock or stony soils (5c, 1).	Very scattered to scattered (2.5-20% PFC) *A. quadrimarginea*, *A. linophylla* or *A. aneura* tall shrublands with sparse *Eremophila* spp. under shrubs (SIMS, SAES, HPMS).
4.	8%	**Gravelly plains** – level or very gently inclined plains with mantles of fine ironstone gravel.	Shallow red clayey sands with ferruginous gravel (2b) or sandy red earths over weathered laterite (4).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (LHMS).
5.	2%	**Drainage tracts** – very gently inclined tracts, rectangularly distributed and usually <50 m wide on upper slopes, becoming broader downslope; often with incised channels to 1.5 m deep.	Shallow red earths on greenstone (7b). Creek bedloads are ironstone, basalt and greenstone cobbles and coarse gravel (12).	Moderately close to close (20-50% PFC) tall shrublands or woodlands of *A. aneura* and other acacias (DRAS).

GRANSAL LAND SYSTEM (800 km², 0.8% of the survey area)

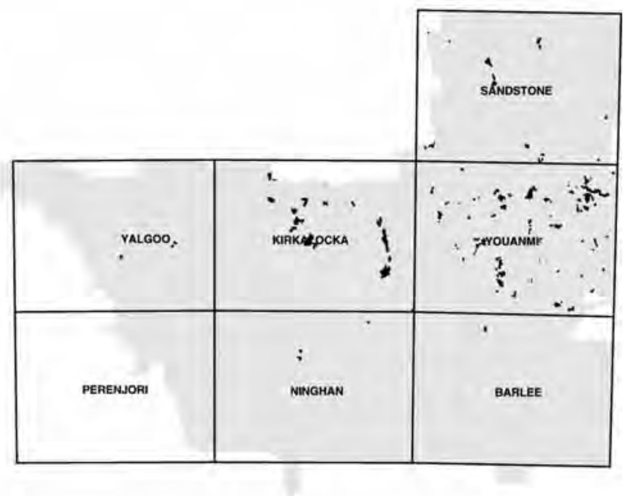
(after Pringle *et al.* 1994)

Stony plains and low rises on granite, supporting mainly halophytic shrublands.

Land type: 8

Geology: Archaean granite and Quaternary colluvium and alluvium.

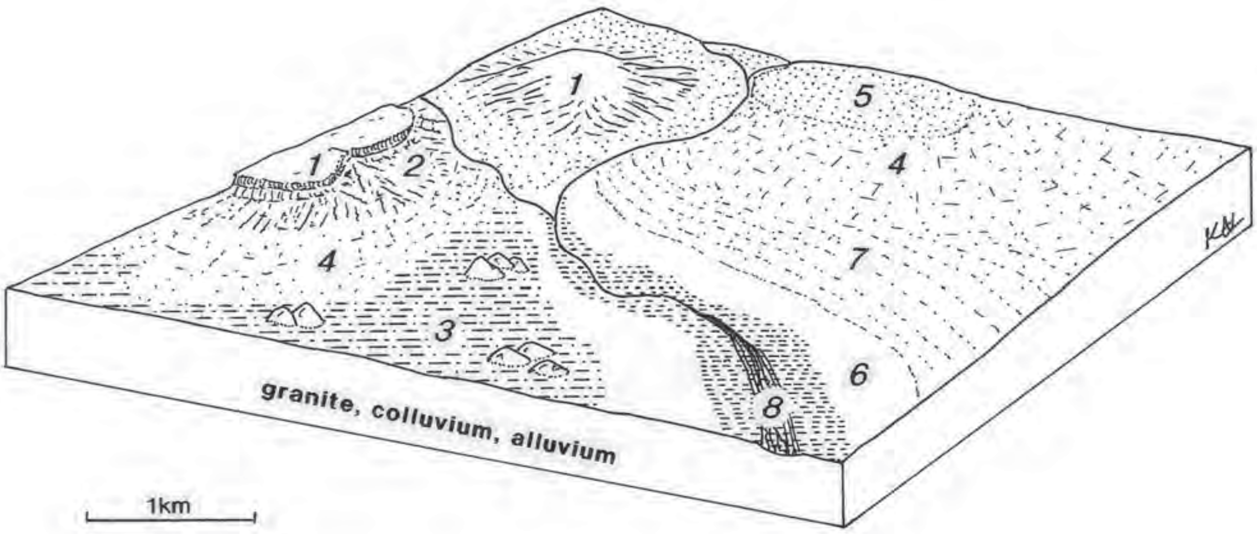
Geomorphology: Erosional surfaces; very occasional low breakaways, tors and rises, extensive plains on deeply weathered granite which have been variably stripped and minor alluvial tracts in lower sectors. Poorly developed drainage patterns.



Land management- Footslopes below breakaways (unit 2), saline stony plains (unit 4) and alluvial plains (unit 6) are moderately susceptible to water erosion in areas where perennial shrub cover is substantially reduced. Disturbance of surface on these units is likely to initiate soil erosion. The vegetation is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (178 assessments):
Vegetation – good 26%; fair 39%; poor 26%; very poor 9%.
Soil erosion – nil 79%; slight 9%; minor 6%; moderate 4%; severe 1%; extreme 1%.

Area mapped as sde: 3.9 km² (0.5% of land system's area).



No.	Unit name	Traverse recordings	Inventory sites
1	Low rise/breakaway	4	1
2	Footslope	4	–
3	Gritty-surfaced plain	21	2
4	Saline stony plain	70	4
5	Stony plain	17	2
6	Alluvial plain	21	3
7	Hardpan plain	36	1
8	Drainage line	13	1
	Other	4	–
	Total	190 *	14

* 12 traverse points not assessed for condition.

Gransal land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Low rises and breakaways** – low rises and granite tors to 15 m high, and occasional low breakaways (to 8 m relief).	Shallow red earths or shallow red clayey sands with a stony mantle on granite (5c, 2d). Soil often confined to pockets of detrital sand on tors (2a).	Very scattered to scattered (2.5-20% PFC) mixed shrublands (GRHS, BRXS).
2.	2%	**Footslopes** – short gentle footslopes below breakaways.	Shallow duplex on weathered granite (7a).	Very scattered to scattered (2.5-20% PFC) mixed halophytic low shrublands with *Maireana pyramidata* (sago bush) often dominant (BCLS).
3.	10%	**Gritty-surfaced plains** – level to gently undulating plains with mantles of fine quartz and granite pebbles, and minor to common granite outcrop.	Shallow coarse red clayey sands or shallow duplex on granite (2a, 7a).	Very scattered to scattered (2.5-20% PFC) mixed shrublands, with *Acacia aneura* (mulga) or *A. quadrimarginea* (granite wattle) tall shrubs (SGRS) on sandy soils. Occasionally scattered low bluebush shrubland on duplex soils (SBMS).
4.	40%	**Saline stony plains** – level to very gently undulating plains with mantles of few to common quartz, granite and ironstone pebbles.	Shallow duplex with a stony mantle, on granite (7a).	Very scattered to scattered (2.5-20% PFC) *Maireana pyramidata* low shrublands (SBMS). *Maireana* species include *M. pyramidata*, *M. triptera* (three-winged bluebush), *M. georgei* (George's) and *M. glomerifolia* (ball-leaf bluebush).
5.	10%	**Stony plains** – level to gently undulating plains with mantles of many to abundant quartz, silcrete and granite pebbles.	Shallow red earths with a stony mantle on granite (5c) and shallow hardpan loams (5d).	Very scattered to scattered (2.5-20% PFC) acacia-eremophila shrublands (SAES).
6.	10%	**Alluvial plains** – nearly level plains in lowest sectors, receiving run-on, rarely channelled.	Shallow duplex on granite or hardpan (7a, 7c).	Very scattered to scattered (2.5-20% PFC) mixed halophytic low shrublands (PXHS) with *M. pyramidata* often dominant (PSAS).
7.	15%	**Hardpan plains** – nearly level plains subject to sheet flow, occasionally with quartz pebble mantles.	Shallow red clayey sands on hardpan (2d).	Scattered (10-20% PFC) *A. aneura* tall shrublands, with non-halophytic and halophytic low shrubs (HPMS, HMCS).
8.	8%	**Drainage lines** – narrow (<50 m wide) areas receiving concentrated run-on.	Shallow red earth or duplex, on granite (5c, 7a).	Moderately close (20-30% PFC) *A. aneura* tall shrublands/woodlands (DRAS).

GRAVES LAND SYSTEM (172 km², 0.2% of the survey area)

(after Pringle *et al.* 1994)

Basalt and greenstone rises and low hills, supporting eucalypt woodlands with prominent saltbush and bluebush understoreys.

Land type: 3

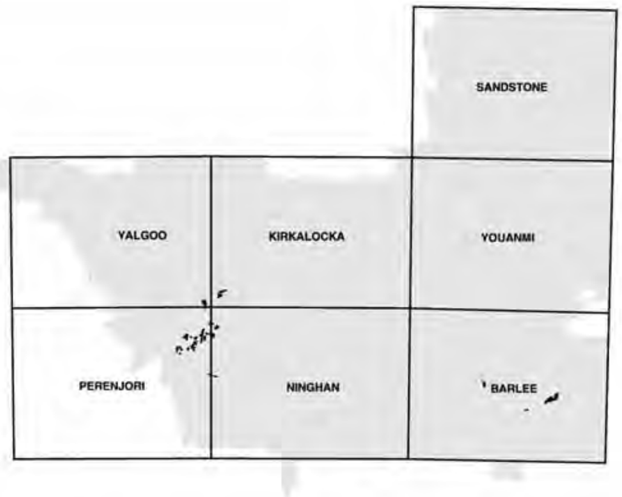
Geology: Archaean basalt and greenstone, minor Tertiary ferruginous duricrust, Quaternary colluvium and alluvium.

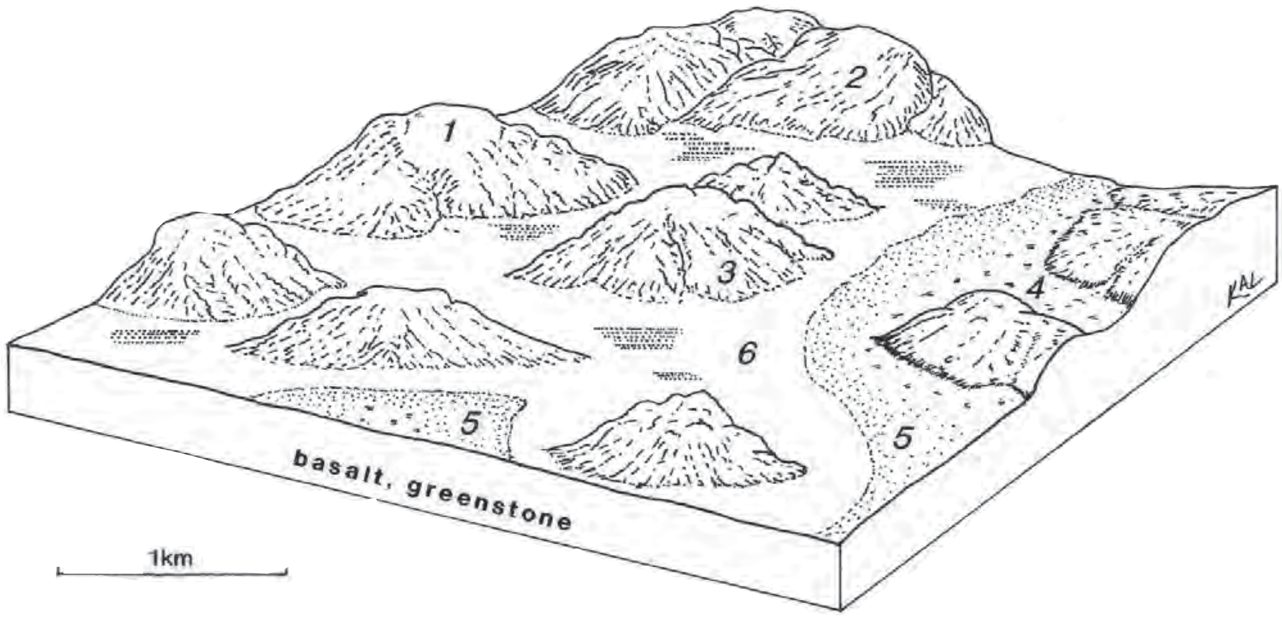
Geomorphology: Erosional surfaces; low rounded hills and rises on weathered material, very gently inclined footslopes with pebble mantles and narrow alluvial tracts.
Relief to 40 m.

Land management: Alluvial plains (unit 6) are susceptible to water erosion where perennial shrub cover is substantially reduced or the soil surface is disturbed. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by control of total grazing pressure.

Traverse condition summary (25 assessments):
Vegetation – good 28%; fair 68%; poor 4%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Low hill and rise	–	1
2	Hillslope	–	1
3	Footslope	1	1
4	Stony plain	12	–
5	Gravelly plain	10	–
6	Alluvial plain	2	1
	Total	25	4

Graves land system

Unit area (%)		Landform	Soil	Vegetation
1.	20%	**Low hills and rises** – rounded and weathered hills and rises with mantles of common to abundant greenstone pebbles and cobbles, generally <25 m relief.	Shallow duplex or shallow calcareous loams, on greenstone (7b, 5a).	Scattered (10-20% PFC) tall and mid height acacia shrublands, occasionally patchy eucalypt woodlands (SIAS, PECW).
2.	15%	**Hillslopes** – gently to moderately inclined slopes with mantles of abundant greenstone pebbles.	Shallow red earths on greenstone or stony soils (5c, 1).	Scattered to moderately close (10-30% PFC) woodlands or tall shrublands of *Casuarina pauper* (black oak) or *Acacia* spp. with *Ptilotus obovatus* (cotton bush) as a prominent low shrub (GHMW).
3.	25%	**Footslopes** – very gently inclined slopes with mantles of few to many greenstone pebbles, occurring downslope of units 1 and 2.	Shallow calcareous loams or deep duplex on greenstone (5a, 8).	Scattered (10-20% PFC) halophytic low shrublands with patchy eucalypt trees; also acacia tall shrublands (PECW, GHAS).
4.	10%	**Stony plains** – level to gently undulating plains with mantles of common to abundant mixed pebbles.	Shallow stony red earths (5b).	Scattered to moderately close (10-30% PFC) tall acacia shrublands with eucalypts, occasionally with halophytic understoreys (GHMW, PECW).
5.	15%	**Gravelly plains** – nearly level plains with mantles of common to abundant fine ironstone gravel.	Shallow red clayey sands with ferruginous mantle (2b).	Moderately close to close (20-50% PFC) tall acacia shrublands with occasional eucalypt trees (PYAW).
6.	15%	**Alluvial plains** – level or very gently inclined drainage tracts, often with mixed pebble mantles, generally <600 m wide, and rarely with gilgai microrelief.	Deep clays, often with a stony mantle (9b), deep red earths (6a), rarely cracking clays (10).	Scattered to moderately (10-30% PFC) close eucalypt woodlands with a prominent low shrub layer of *Atriplex* spp. (saltbush) (PECW).

GUMBREAK LAND SYSTEM (382 km², 0.4% of the survey area)

(after Pringle *et al.* 1994)

Low granite breakaways and saline alluvial plains supporting halophytic shrublands.

Land type: 5

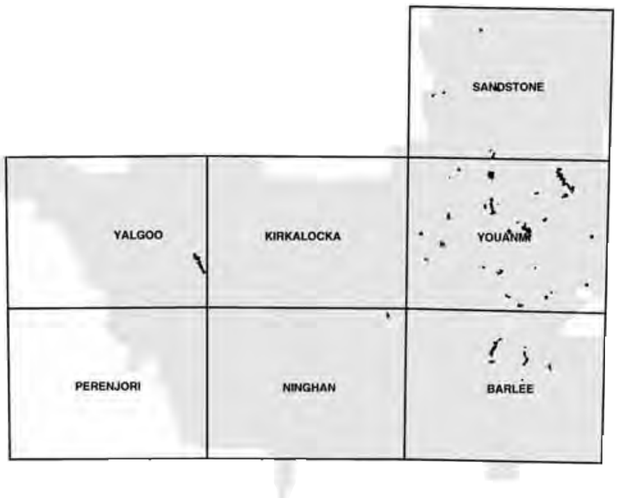
Geology: Archaean granite and gneiss with Quaternary colluvium and alluvium.

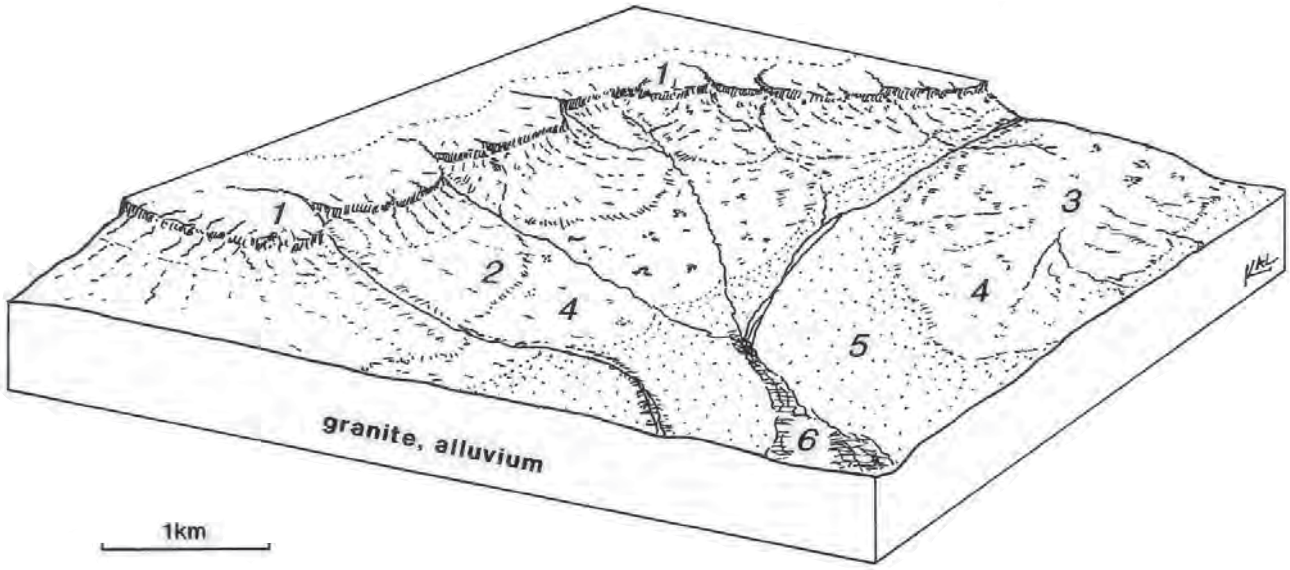
Geomorphology: Erosional and depositional surfaces; low breakaways with footslopes on pallid zone material upslope of plains with grit and stone mantles and plains of alluvium receiving unchannelled flow.

Land management: Lower footslopes (unit 2) and alluvial plains (unit 5) are moderately susceptible to soil erosion where perennial shrub cover is reduced. In these areas and on stony saline plains (unit 4), disturbance to the soil surface is likely to initiate soil erosion. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (62 assessments):
Vegetation – good 42%; fair 23%; poor 27%; very poor 8%.
Soil erosion – nil 87%; slight 5%; minor 5%; moderate 3%.

Area mapped as sde: 1.2 km² (0.3% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway	6	2
2	Lower footslope	9	3
3	Gritty-surfaced plain	6	1
4	Stony saline plain	18	–
5	Alluvial plain	17	4
6	Drainage line	3	–
	Other	7	–
	Total	66 *	10

* 4 traverse points not assessed for condition.

Gumbreak land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Breakaways** – low breakaways on granite (up to 25 m relief); narrow duricrusted plateaux with outcrop and mantles of granite and silcrete with moderately inclined to steep breakaway faces, and gently inclined short upper footslopes.	Stony soils on crests (1), shallow duplex with a stony mantle on granite on upper footslopes (7a).	Very scattered (2.5-10% PFC) low heath shrublands (BRXS) on plateaux; scattered halophytic low shrublands (USBS) on upper footslopes.
2.	15%	**Lower footslopes** – very gently inclined lower footslopes, with tributary drainage.	Shallow duplex on granite (7a).	Scattered (10-20% PFC) halophytic low shrublands, common species include *Atriplex vesicaria* (bladder saltbush), *Maireana* spp. (bluebush) and *Frankenia* spp. (frankenia) (BCLS). Occasionally scattered (10-20% PFC) eucalypt woodlands with *Atriplex* spp. understoreys (BECW).
3.	10%	**Gritty-surfaced plains** – level to gently undulating plains with fine quartz gravel and granite outcrop.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) mixed shrublands, often with *Acacia quadrimarginea* (granite wattle) (SGRS).
4.	30%	**Stony saline plains** – level to gently undulating plains, with a mantle of granite or quartz pebbles.	Shallow duplex with a stony mantle, on granite (7a).	Very scattered to scattered (2.5-20% PFC) *Maireana* spp. (bluebush) low shrublands (SBMS).
5.	30%	**Alluvial plains** – nearly level plains receiving concentrated flow.	Shallow duplex on granite or hardpan (7a, 7c).	Scattered (10-20% PFC) halophytic low shrubland commonly with *Maireana pyramidata* (sago bush) dominant and occasionally with a eucalypt overstorey (PSAS, PXHS).
6.	5%	**Drainage lines** – mostly unchannelled flow zones, receiving concentrated drainage from upper units.	Shallow duplex on granite (7a).	Moderately close (20-30% PFC) *Acacia aneura* (mulga) tall shrublands with mixed halophytic and non-halophytic low shrubs (DMCS).

HAMILTON LAND SYSTEM (325 km^2, 0.3% of the survey area)

(ater Pringle *et al.* 1994)

Hardpan plains and stony plains with mulga shrublands.

Land type: 13

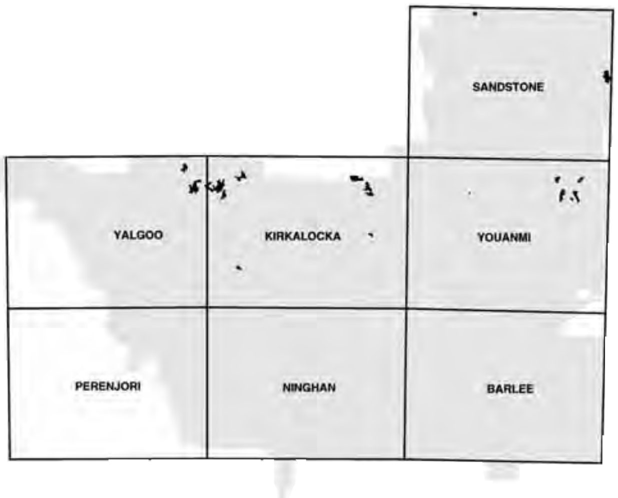
Geology: Partly cemented Quaternary alluvium and colluvium, minor Archaean granite.

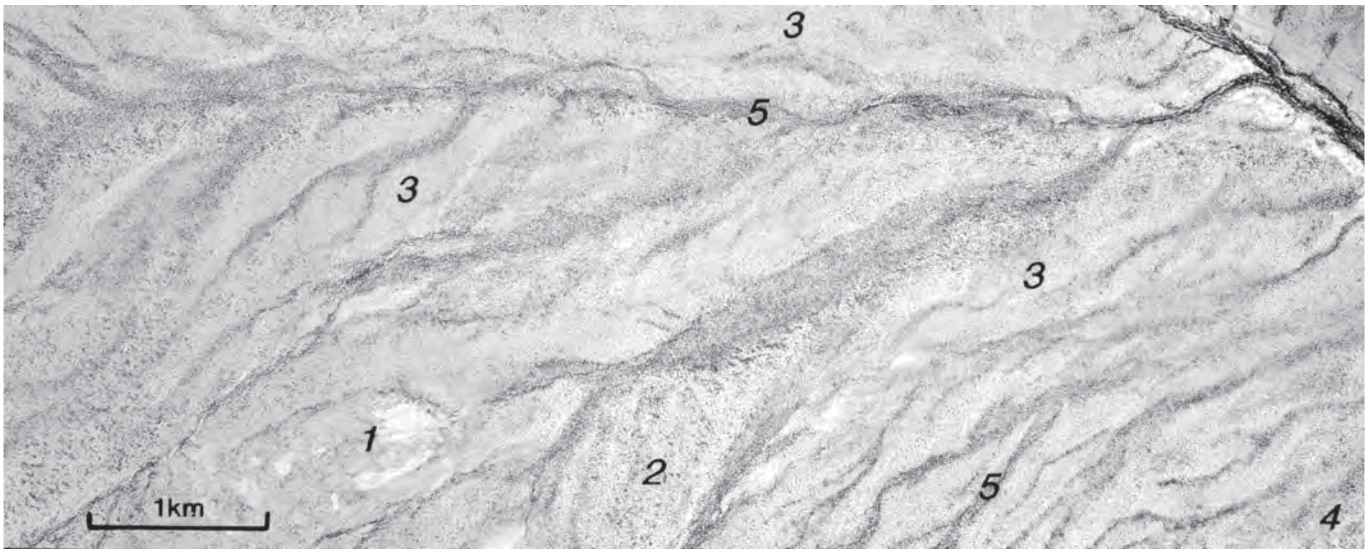
Geomorphology: Depositional surfaces; level to gently undulating plains with occasional irregular sandy banks upslope of drainage tracts with numerous narrow, often incised (to 5 m) channels which are dendritic in upper parts.

Land management: Hardpan plains (unit 1) and drainage lines (unit 5) are mildly susceptible to water erosion. Alteration of natural water flows can initiate erosion and cause water starvation and consequent loss of vigour in vegetation downslope.

Traverse condition summary (70 ratings):
Vegetation – good 21%; fair 49%; poor 26%; very poor 4%.
Soil erosion – nil 95%; slight 4%; moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Stony plain	4	–
2	Stony hardpan plain	6	2
3	Hardpan plain	44	3
4	Sandy bank	5	–
5	Drainage line	7	2
	Other	5	–
	Total	71 *	7

* 1 traverse point not assessed for condition.

Hamilton land system

Unit area (%)		Landform	Soil	Vegetation
1.	10%	**Stony plains** – level to gently undulating plains and interfluves with quartz pebble mantles.	Shallow red earths or shallow duplex with a stony mantle, on granite (5c, 7a).	Scattered (10-20% PFC) acacia-eremophila shrublands (SAES) occasionally with halophytic low shrubs (USBS).
2.	15%	**Stony hardpan plains** – level to very gently inclined plains subject to sheet flow, with mantles of common quartz pebbles.	Shallow red earths with a stony mantle on hardpan over granite (5c).	Scattered to moderately close (10-30% PFC) *Acacia aneura* (mulga), *A. ramulosa* (bowgada) and *Eremophila* spp. tall shrublands (SAES, HPMS).
3.	60%	**Hardpan plains** – nearly level plains subject to sheet flow.	Shallow red earths (5c) or shallow red clayey sands on hardpan (2d).	Scattered to moderately close (10-30% PFC) *A. aneura* tall shrublands with *Eremophila* spp. low and mid shrubs (HPMS).
4.	5%	**Sandy banks** – slightly elevated irregular sandy banks on units 1 and 2.	Deep red clayey sands, or sandy red earths on hardpan (3a, 4).	Scattered (10-20% PFC) mixed shrublands with a wanderrie grass understorey (WABS).
5.	10%	**Drainage lines** – narrow flow zones with channels incised (to 5 m deep) into hardpan; dendritic in upper parts.	Shallow red clays on floors (9a); channel bedloads are large pebbles of granite and quartz (12), exposure of hardpan and granite along channels.	Scattered to moderately close (10-30% PFC) *A. aneura* tall shrublands (DRAS).

HOOTANUI LAND SYSTEM (423 km², 0.4% of the survey area)

(after Pringle *et al.* 1994)

Breakaways, hills and ridges with saline gravelly and stony lower plains supporting scattered halophytic low shrublands.

Land type: 5

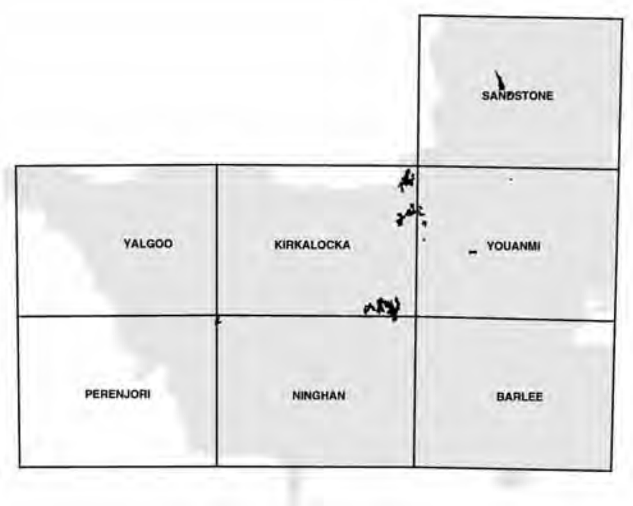
Geology: Archaean greenstone, basalt and felsic rocks, Tertiary limonite, Quaternary colluvium and alluvium.

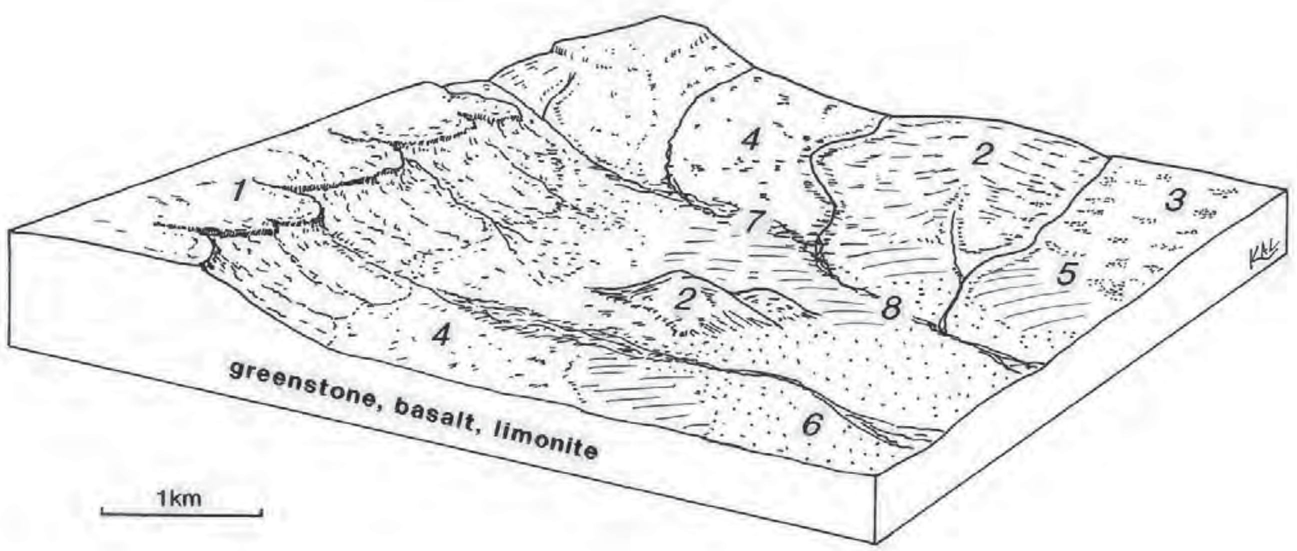
Geomorphology: Erosional and depositional surfaces; breakaways and low hills with very gently to gently inclined footslopes with gravelly mantles upslope from extensive plains of alluvium with pebble mantles and narrow, sparse tributary drainage tracts. Relief to 30 m.

Land management: Narrow drainage tracts (unit 7) and breakaway footslopes (unit 1) are susceptible to water erosion in areas where perennial shrub cover is substantially reduced or the soil surface is disturbed. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (92 assessments):
Vegetation – good 12%; fair 42%; poor 36%; very poor 10%
Soil erosion – nil 85%; slight 10%; moderate 5%.

Area mapped as sde: 0.8 km² (0.2% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway	3	2
2	Hill and ridge	4	3
3	Stony plain	8	–
4	Saline stony plain	35	7
5	Alluvial plain	14	3
6	Highly saline plain	20	6
7	Narrow drainage tract	10	4
8	Creekline	–	–
	Total	94 *	25

* 2 traverse points not assessed for condition.

Hootanui land system

Unit	area (%)	Landform	Soil	Vegetation
1.	7%	**Breakaways** – partly stripped duricrusted plateaux, escarpments to 20 m with scree slopes and short (<150 m) gravelly surfaced footslopes on weathered rock.	Stony soils and very shallow coarse red clayey sands (1, 2a).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrublands on stripped surfaces (SIMS) with halophytic low shrub communities on the footslopes (BCLS).
2.	5%	**Hills and ridges** – rounded hills (to 30 m relief) frequently with limonitic capping and gently inclined footslopes, occasional ironstone ridges to 30 m.	Stony soils and shallow red earths on greenstone (1, 5c).	Scattered (10-20% PFC) *A. aneura* shrublands (SIMS), occasionally with halophytic understoreys on more saline footslopes (USBS, occasionally SAMP).
3.	8%	**Stony plains** – gently undulating plains with mantles of abundant quartz and ironstone pebbles.	Stony soils (1).	Very scattered to scattered (2.5-20% PFC) acacia – eremophila shrublands (SAES).
4.	35%	**Saline stony plains** – extensive level to very gently inclined plains with mantles of abundant quartz and ironstone pebbles.	Shallow duplex on greenstone or hardpan (7b, 7c); shallow red clayey sands on weathered parent material (2d).	Very scattered to scattered (2.5-20% PFC) variable halophytic low shrublands often with sparse *A. aneura* or *A. eremaea* (snakewood) tall shrubs (SBMS, USBS).
5.	15%	**Alluvial plains** – nearly level plains with mantles of fine ironstone gravel, receiving tributary flow from units 1, 2 and 3.	Shallow duplex on hardpan (7c).	Very scattered to scattered (2.5-20% PFC) halophytic low shrublands (PXHS), often dominated by *Maireana pyramidata* (sago bush) (PSAS).
6.	20%	**Highly saline plains** – level to very gently inclined plains with mantles of fine and medium ironstone gravel and pebbles, subject to sheet flow.	Saline deep clays and duplex soils (9b, 8).	Scattered (10-20% PFC) *Halosarcia* spp. (samphire) low shrublands (SAMP) or other halophytic low shrublands (PXHS).
7.	10%	**Narrow drainage tracts** – usually <150 m wide, level to very gently inclined zones receiving concentrated tributary drainage; minor shallow (<30 cm deep) channels.	Shallow duplex (7b), also shallow red earths and red clayey sands over parent material (5c, 2d).	Very scattered to scattered (2.5-20% PFC) halophytic low shrublands (PXHS, PSAS). Also scattered tall shrublands with *A. aneura.*
8.	<1%	**Creeklines** – occasional narrow creeks (usually <10 m wide and <2 m deep) with steep-sided banks.	Juvenile soils and bedload deposits of water-smoothed pebbles and cobbles (12).	Moderately close (20-30% PFC) acacia tall shrublands with occasional *Eucalyptus camaldulensis* (river red gum) trees (CBKW).

ILLAARA LAND SYSTEM (202 km², 0.2% of the survey area)

(after Pringle *et al.* 1994)

Gravelly plains supporting mulga-casuarina shrublands.

Land type: 16

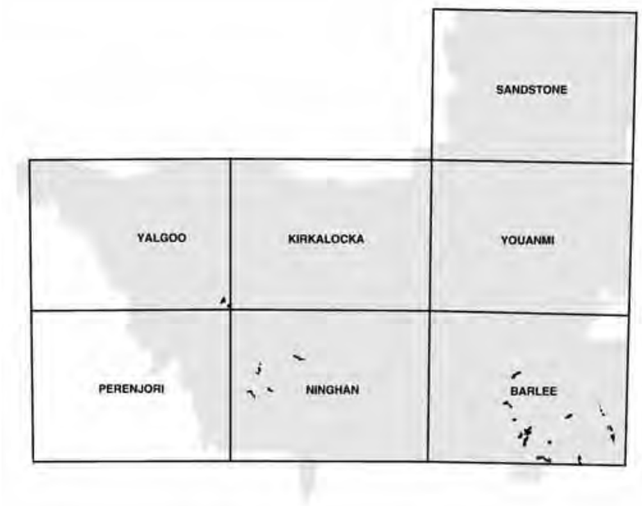
Geology: Quaternary eluvium.

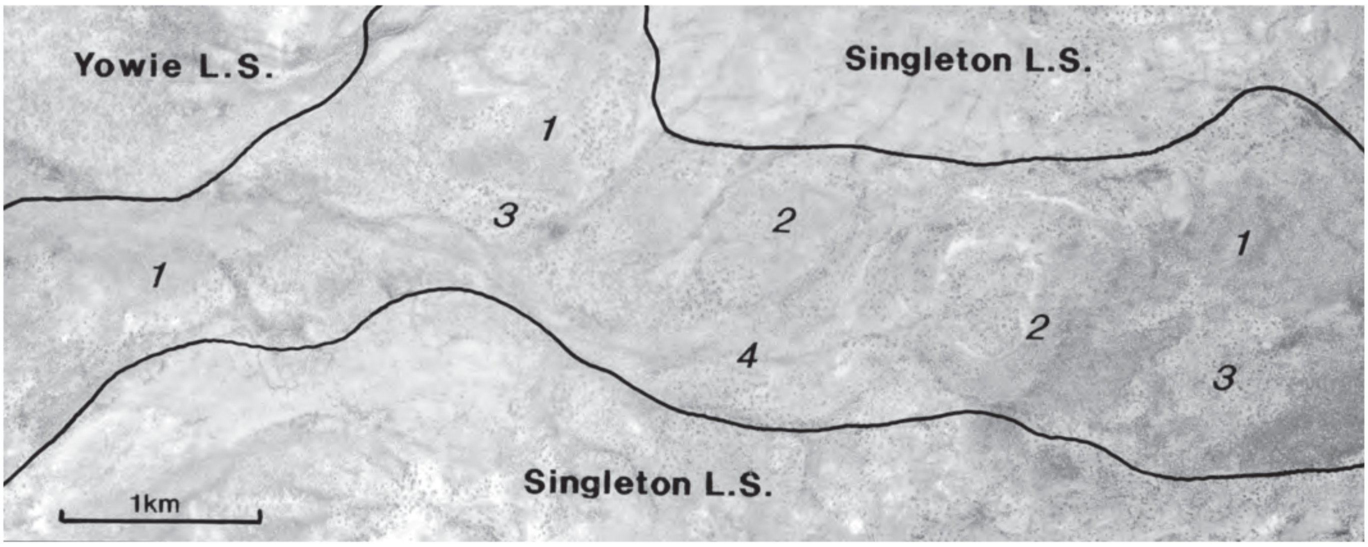
Geomorphology: Mainly depositional surfaces; gently undulating plains and occasional low rises with ironstone gravel mantles, slightly lower level to gently undulating plains with calcrete rubble. Poorly defined surface drainage patterns.

Land management: This land system is generally not susceptible to soil erosion.

Traverse condition summary (21 assessments): Vegetation – good 62%; fair 38%; poor 0%; very poor 0%. Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Gravelly or stony plain	14	4
2	Lateritic rise	1	–
3	Loamy plain	3	1
4	Drainage line	1	–
	Other	2	–
	Total	21	5

Illaara land system

Unit	area (%)	Landform	Soil	Vegetation
1.	80%	**Gravelly or stony plains** – gently undulating plains with a mantle of fine and medium ironstone gravel and quartz pebbles, and locally with calcrete rubble.	Shallow red earths and red clayey sands with ferruginous lag (5c, 2d). Occasional shallow calcareous loams (5a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with *Casuarina pauper* (black oak) overstoreys (CCAS, SIAS).
2.	5%	**Lateritic rises** – low rises with abundant ironstone gravel mantles on unit 1.	Stony soils and shallow red clayey sands with ferruginous gravel (1, 2b).	Moderately close (20-30% PFC) acacia tall shrublands (SIAS).
3.	10%	**Loamy plains** – gently undulating plains which may have a mantle of ironstone gravel.	Deep calcareous red earths (6b).	Scattered (10-20% PFC) acacia tall shrublands with *Eucalyptus loxophleba* (York gum) overstorey (PYAW).
4.	5%	**Drainage lines** – sparse unchannelled irregular flow lines.	Deep red earths (6a).	Close (30-50% PFC) *Acacia aneura* (mulga) shrublands and woodlands (DRAS).

JOSEPH LAND SYSTEM (4,612 km², 4.9% of the survey area)

Undulating yellow sandplain supporting dense mixed shrublands with patchy mallees.

Land type: 11

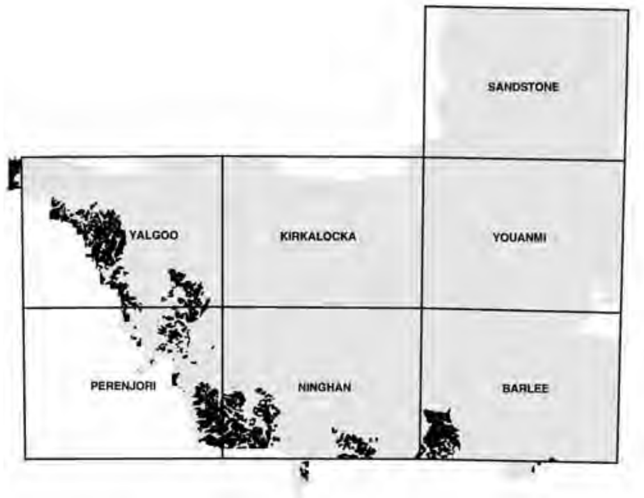
Geology: Cainozoic alluvial and colluvial sand deposits and minor Archaean granite.

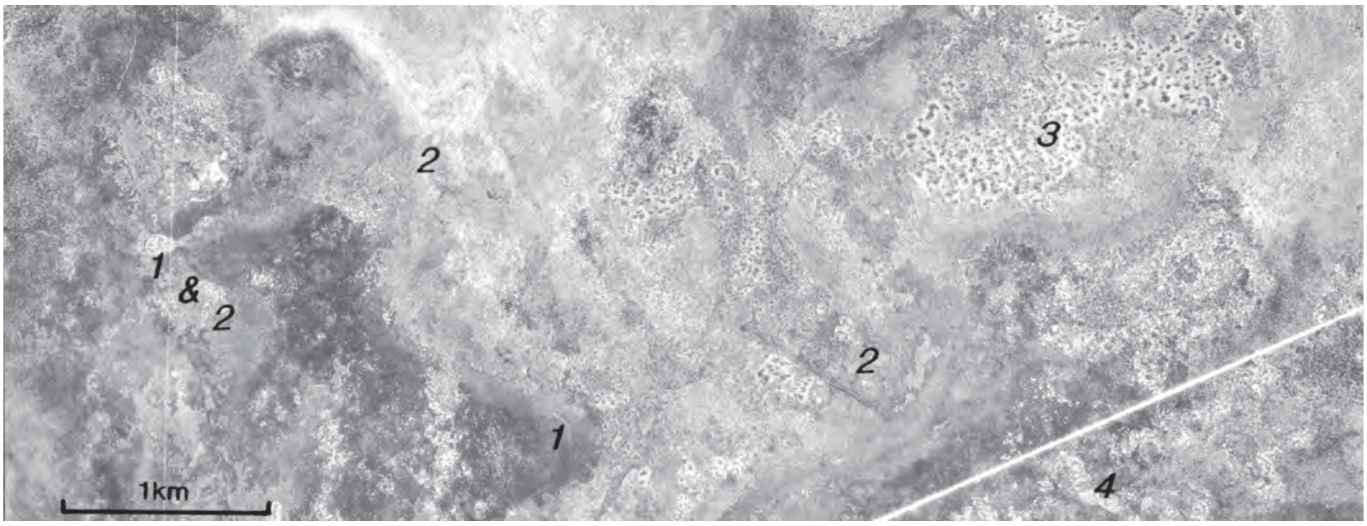
Geomorphology: Depositional surfaces; level to undulating sand sheets, lower areas have ironstone gravel mantles and plains which receive diffuse run-on. Minor areas of granite outcrop.

Land management: The very dense and largely unpalatable vegetation on this system means that most of it is unsuitable for pastoralism. The vegetation is also too dense for vehicular access. In its natural state the system is not susceptible to soil erosion. The system is subject to occasional highly intense and extensive wildfires.

Traverse condition summary (296 assessments):
Vegetation – good 87%; fair 12%; poor 1%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Gravelly sand sheet	65	7
2	Sand sheet	155	9
3	Loamy plain	52	3
4	Gritty-surfaced plain	21	–
	Other	4	–
	Total	297 *	19

* 1 traverse point not assessed for condition.

Joseph land system

Unit	area (%)	Landform	Soil	Vegetation
1.	20%	**Gravelly sand sheets** – level to gently undulating sand sheet with mantles of few ironstone gravel and pebbles.	Yellow clayey sands on ironstone gravel at variable depth (3b, 2e).	Close (30-50% PFC) mixed shrublands commonly with acacia, melaleuca and allocasuarina mid and tall shrubs, and low heath shrubs (SCMS) or moderately close to close (20-50% PFC) acacia tall shrublands with an *Amphipogon caricinus* (grey beard grass) layer (LACS).
2.	60%	**Sand sheets** – level to undulating sand sheet higher than unit 1.	Deep yellow and red clayey sands (3b, 3a).	Close to closed (>30% PFC) mixed shrublands commonly with acacia and melaleuca tall shrubs and low heath shrubs such as *Eriostemon* and *Thryptomene* (SCMS) or moderately close to close (20-50% PFC) acacia tall shrubland (SACS).
3.	15%	**Loamy plains** – level plain receiving diffuse run-on.	Variable shallow red clayey sands on granite (2d), sandy red earths and occasional deep clays (4, 9b).	Scattered (10-20% PFC) eucalypt woodland with tall *Acacia ramulosa* (bowgada) and mixed low shrubs (PYAW) or moderately close (20-30% PFC) *A. ramulosa* tall shrubland (SACS).
4.	5%	**Gritty-surfaced plains** – plains with common granite outcrop and gritty or stony mantles, and occasional gravelly stripped surfaces; occurs as small inliers within units 1 and 2.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) acacia tall shrublands often with *Borya sphaerocephala* in the ground layer (GABS), and very scattered (2.5-10% PFC) low myrtaceous shrublands (BRXS).

JOY LAND SYSTEM (19 km^2, 0.02% of the survey area)

Saline alluvial plains, small creeklines and sandy banks supporting halophytic low shrublands locally with spiny snakewood overstoreys.

Land type: 17

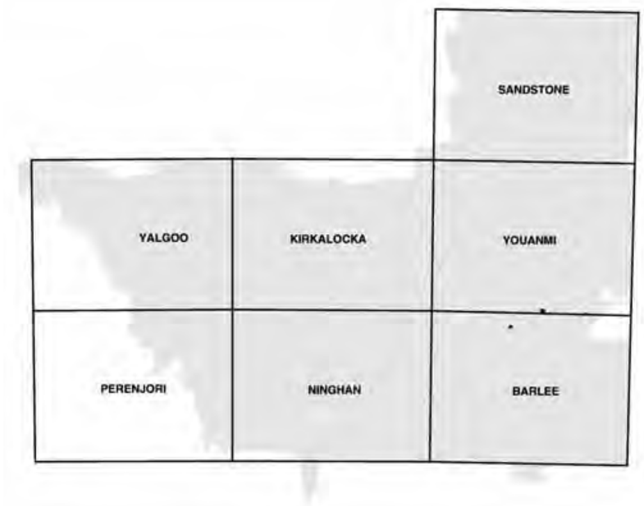
Geology: Quaternary alluvium.

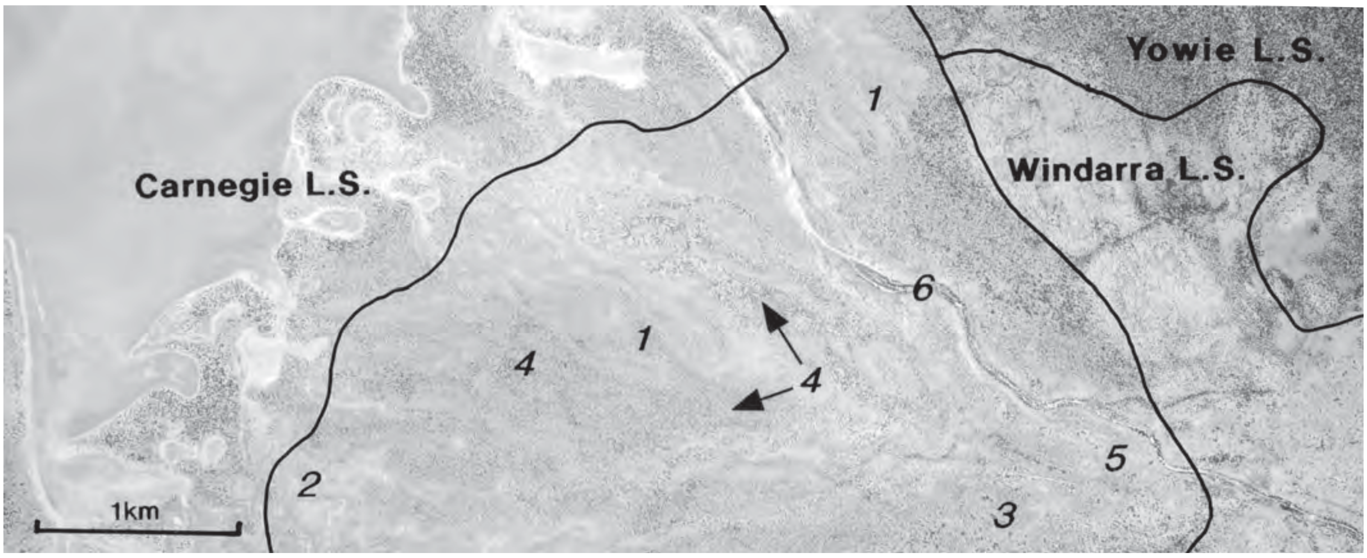
Geomorphology: Depositional surfaces; alluvial plains tributary to salt lakes, with low sandy banks and occasional creeklines.

Land management: The alluvial plains (unit 1) are moderately susceptible to water erosion if perennial shrub cover is reduced and/or the soil disturbed. The vegetation is highly preferred for grazing by introduced and native animals, rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be overcome by appropriate management, including control of total grazing pressure.

Traverse condition summary (6 assessments):
Vegetation – good 83%; fair 17%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Alluvial plain	2	1
2	Saline alluvial plain	–	–
3	Hardpan plain	–	–
4	Sandy bank	4	1
5	Narrow drainage line	–	1
6	Creekline	–	1
	Total	6	4

Joy land system

Unit	area (%)	Landform	Soil	Vegetation
1.	35%	**Alluvial plains** – nearly level plains, usually less than 500 m wide, between sandy banks, carrying sheet flow to salt lakes; minor shallow channels.	Shallow duplex and red clayey sands on hardpan (7c, 2d).	Scattered (10-20% PFC) halophytic low shrublands commonly with *Atriplex bunburyana* (silver saltbush) dominant (SSAS, PXHS).
2.	10%	Saline alluvial plains – plains and depressions adjacent to salt lakes.	Deep clays (9b).	Scattered to moderately close (10-30% PFC) halophytic low shrublands commonly dominated by *Halosarcia* spp. (samphires) (SAMP).
3.	12%	**Hardpan plains** – nearly level alluvial plains, often fringing unit 4, carrying sheet flow from upslope.	Shallow red earths on hardpan (5c).	Scattered (10-20% PFC) acacia tall shrublands with sparse halophytic understoreys (HMCS).
4.	35%	**Sandy banks** – nearly linear, narrow (<200 m wide) low sandy banks, marginally (<50 cm) higher than adjacent alluvial plains (unit 1).	Deep red clayey sands on hardpan (3a).	Scattered (10-20% PFC) *Acacia masliniana* (spiny snakewood) tall shrublands with an halophytic understorey (ASWS, SBLS).
5.	5%	**Narrow drainage lines** – nearly linear, narrow (<200 m wide) zones through unit 1, carrying more concentrated flow off granites upslope.	Shallow red clayey sands on hardpan (2d).	Scattered (10-20% PFC) *A. masliniana* tall shrublands with an halophytic understorey (ASWS).
6.	3%	**Creeklines** – narrow (<30 m wide) creeklines incised to 2.5 m deep with exposed hardpan.	Juvenile soils of coarse sand and pebble bedloads (12).	Scattered to moderately close (10-30% PFC) *Callistemon phoeniceus* (lesser bottlebrush) tall shrublands, with sclerophyll understoreys (CBBS).

JUNDEE LAND SYSTEM (1,333 km^2, 1.4% of the survey area)

(after Mabbutt *et al.* 1963)

Hardpan plains with ironstone gravel mantles supporting mulga shrublands.

Land type: 13

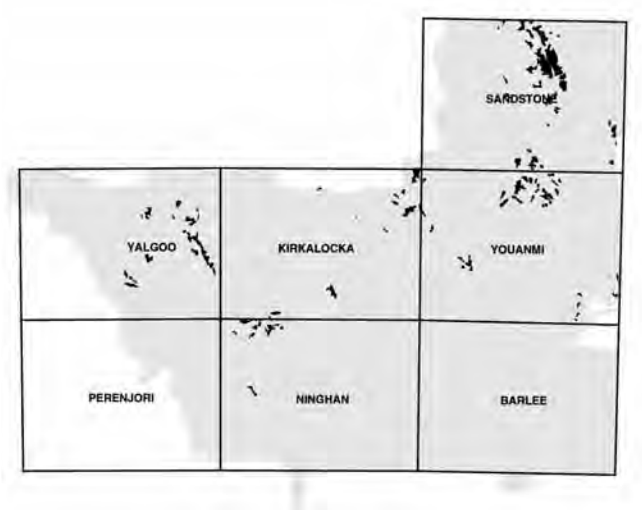
Geology: Cemented Quaternary alluvium derived mainly from greenstone uplands.

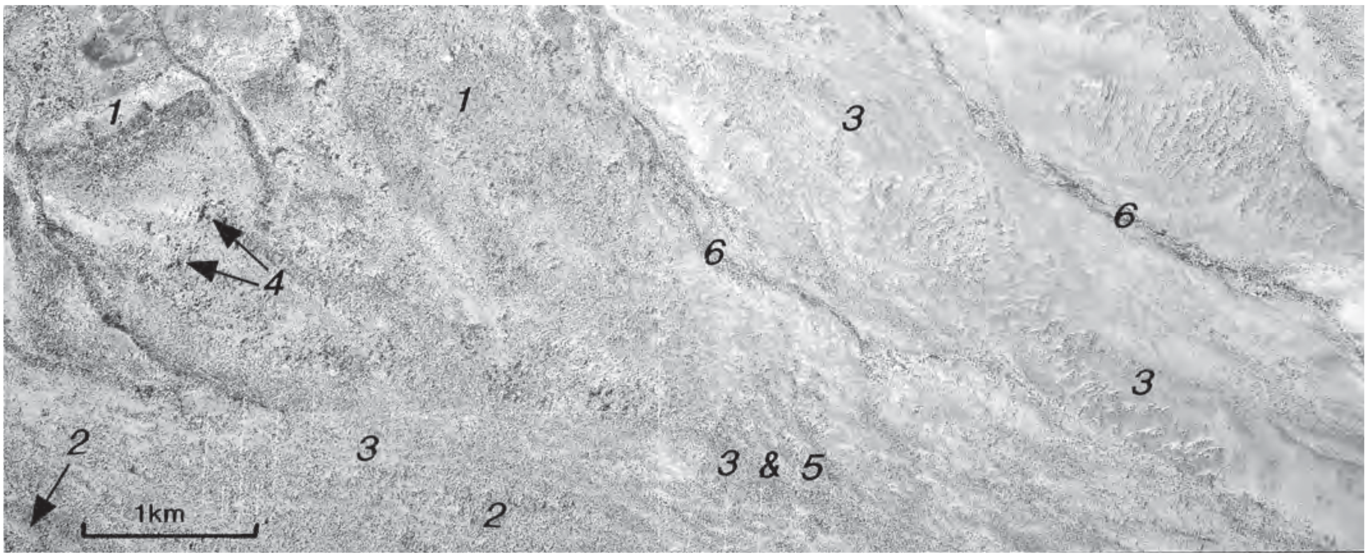
Geomorphology: Depositional surfaces; level to gently inclined plains with mantles of fine ironstone gravel, subject to sheet flow, also drainage tracts receiving more concentrated run-on and with shallow channels; occasional irregular low sandy tracts and banks.

Land management: Alteration to natural sheet flows can initiate soil erosion and cause water starvation and consequent loss of vigour in vegetation downslope.

Traverse condition summary (161 assessments):
Vegetation – good 42%; fair 34%; poor 14%; very poor 10%.
Soil erosion – nil 95%; slight 1%; minor 2%; moderate 1%; severe 1%.

Area mapped as sde: 12 km^2 (0.9% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Stony hardpan plain	38	2
2	Loamy plain	12	–
3	Hardpan plain	104	6
4	Grove	4	–
5	Sandy bank	3	–
6	Drainage tract	23	1
	Other	2	–
	Total	186	9

* 25 traverse points not assessed for condition.

Jundee land system

Unit area (%)		Landform	Soil	Vegetation
1.	20%	**Stony hardpan plains** – gently inclined upper plains with mantles of ironstone and quartz pebbles.	Shallow red earths with a stony mantle, on hardpan (5c).	Scattered (10-20% PFC) acacia-eremophila shrubland (SAES) in upper sectors and scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrublands (LHMS) in lower areas.
2.	5%	**Loamy plains** – level plains very slightly higher than unit 3, subject to diffuse run-on.	Deep red clayey sands or deep red earths (3a, 6a).	Scattered (10-20% PFC) *A. aneura* tall shrublands (PLMS).
3.	60%	**Hardpan plains** – level to very gently inclined plains usually with mantles of fine ironstone gravel, subject to sheet flow.	Shallow hardpan loams or red clayey sands on hardpan (5d, 2d), with deep red earths, occasionally on hardpan (6a).	Scattered (10-20% PFC) to moderately close *A. aneura* tall shrublands (LHMS, HPMS).
4.	2%	**Groves** – narrow, elliptical drainage foci (to 30 m wide and 200 m long but usually much less) arranged transversely to direction of sheet flow on units 1 and 3.	Deep red earths (6a).	Moderately close to closed (>20% PFC) *A. aneura* tall shrublands or woodlands (GRMU).
5.	3%	**Sandy banks** – occasional irregular low (<30 cm) banks with mantles of fine ironstone gravel, on unit 3.	Deep red clayey sands or sandy red earths, on hardpan (3a, 4).	Scattered (10-20% PFC) *A. aneura* tall shrublands with wanderrie grasses (WABS).
6.	10%	**Drainage tracts** – narrow, (usually <500 m wide) tracts receiving concentrated run-on, with occasional shallow channels.	Red earths on hardpan at variable depth (5c, 5d).	Scattered to moderately close (20-30% PFC) *A. aneura* tall shrublands (DRAS).

KALLI LAND SYSTEM (4,954 km^2, 5.2% of the survey area)

(after Mabbutt *et al.* 1963)

Red sandplains supporting bowgada shrublands with wanderrie grasses.

Land type: 12

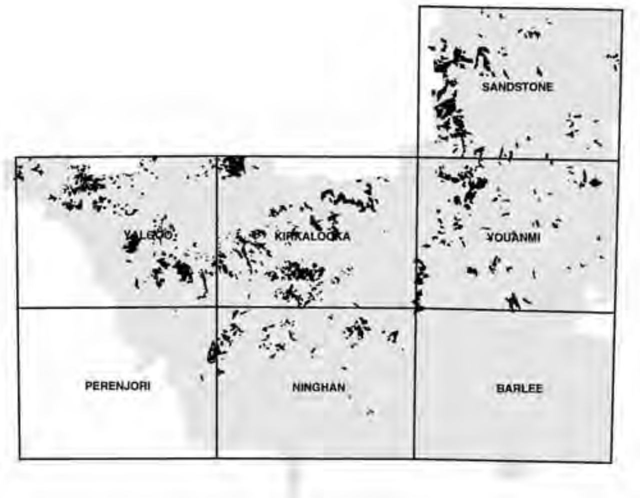
Geology: Quaternary aeolian sand derived from Archaean gneiss and granite, local Tertiary laterite.

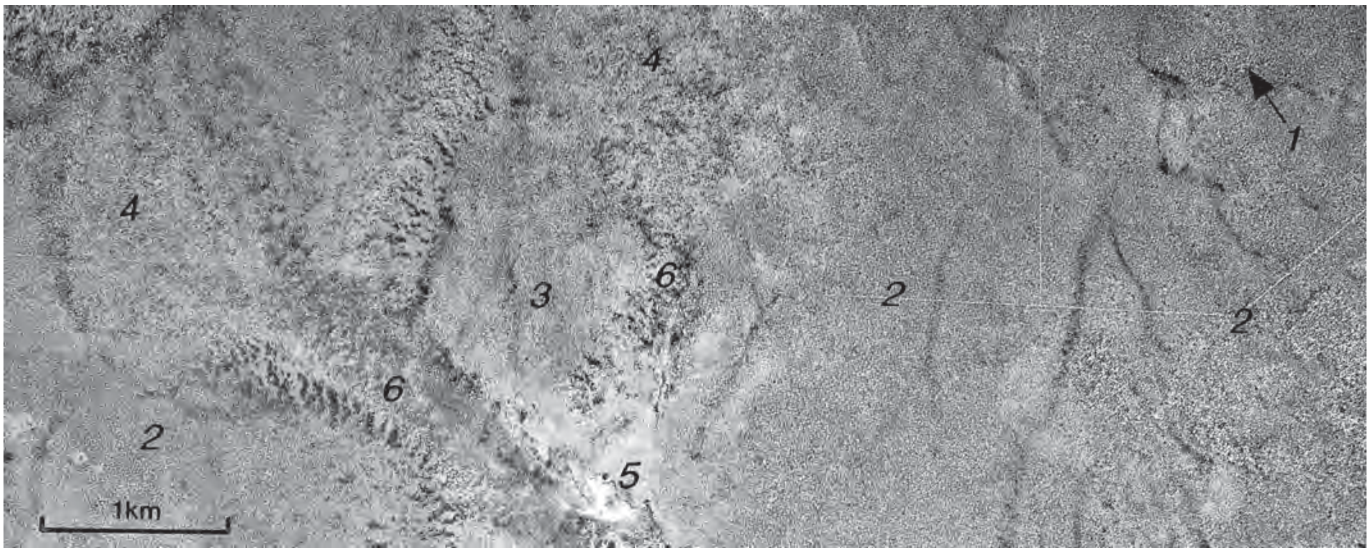
Geomorphology: Depositional surfaces; residual plateau surfaces with level to gently undulating sandplains high in the landscape, with occasional low linear dunes and exposed duricrust; infrequent drainage features, mostly diffuse and internal, but with some broad lightly stripped alluvial tracts with groved vegetation. Overall relief to about 20 m.

Land management: The system not normally susceptible to accelerated erosion, although vehicular tracks can cause local gullying on steeper gradients; dense vegetation protects the soil from wind erosion.

Traverse condition summary (435 assessments):
Vegetation – good 69%; fair 24%; poor 6%; very poor 1%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sand dune	2	–
2	Sandplain	237	14
3	Gravelly sandplain	34	4
4	Loamy plain	130	–
5	Stripped surface	11	–
6	Alluvial tract	26	2
	Other	5	–
	Total	445 *	20

* 10 traverse points not assessed for condition.

Kalli land system

Unit	area (%)	Landform	Soil	Vegetation
1.	<1%	**Sand dunes** – linear dunes to about 6 m high and 1 km in length.	Deep red sands (3c).	Scattered to moderately close (10-30% PFC) acacia shrublands (SDSH).
2.	60%	**Sandplains** – level to gently undulating plains up to 5 or 6 km in extent with relief to 10 m.	Deep red clayey sands, occasionally overlying ferruginous gravels at <1 m (3a).	Moderately close to close (10-50% PFC) tall shrublands of *Acacia ramulosa* (bowgada) and *A. coolgardiensis* (sugar brother) with wanderrie grasses; occasional mallees and *Callitris glaucophylla* (native pine) (SWGS, SACS, MAAS, PINW).
3.	10%	**Gravelly sandplains** – very gently inclined plains, usually adjacent to stripped surfaces (unit 5), and occasional isolated gritty-surfaced tracts with granite outcrop.	Shallow red clayey sands over ferruginous gravels (2d).	Scattered to moderately close (10-30% PFC) mixed height shrublands of *Acacia* spp., myrtaceous low shrubs and *Amphipogon caricinus* (grey beard grass) (SWGS, SACS, LSHE).
4.	22%	**Loamy plains** – very gently inclined plains subject to diffuse run-on.	Sandy red earths and deep red clayey sands (4, 3a).	Moderately close to close (20-50% PFC) tall shrublands of *Acacia aneura* (mulga) and *A. ramulosa* with scattered wanderrie grasses (MUBW, PLMS, SWGS).
5.	3%	**Stripped surfaces** – very gently inclined plains with mantles of common to abundant ironstone and ferruginous gravel.	Shallow coarse clayey sands over laterite or deeply weathered granite (2a).	Very scattered to moderately close (2.5-30% PFC) often including acacias, eremophilas, and *Thryptomene decussata* and other myrtaceous shrubs (BRXS).
6.	5%	**Alluvial tracts** – very gently inclined broad fans and unchannelled drainage tracts, with areas of sheet flow; occasionally with gravelly mantles.	Shallow and deep red earths (5c, 6a).	Close (30-50% PFC) tall shrublands or woodlands of *A. aneura* and *A. ramulosa* (GRMU) in groves; elsewhere scattered to moderately close (10-30% PFC) acacia tall shrublands (HPMS, DRAS).

LAWRENCE LAND SYSTEM (4 km^2, <0.01% of the survey area)

(after Pringle *et al.* 1994)

Low greenstone hills with ironstone ridges supporting pearl bluebush shrublands and eucalypt woodlands with halophytic undershrubs.

Land type: 3

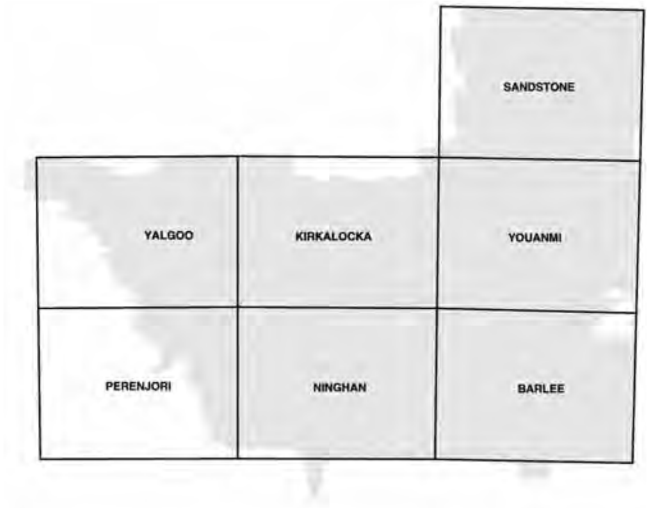
Geology: Archaean greenstone, basalt and banded ironstone formation, Quaternary colluvium and minor alluvium.

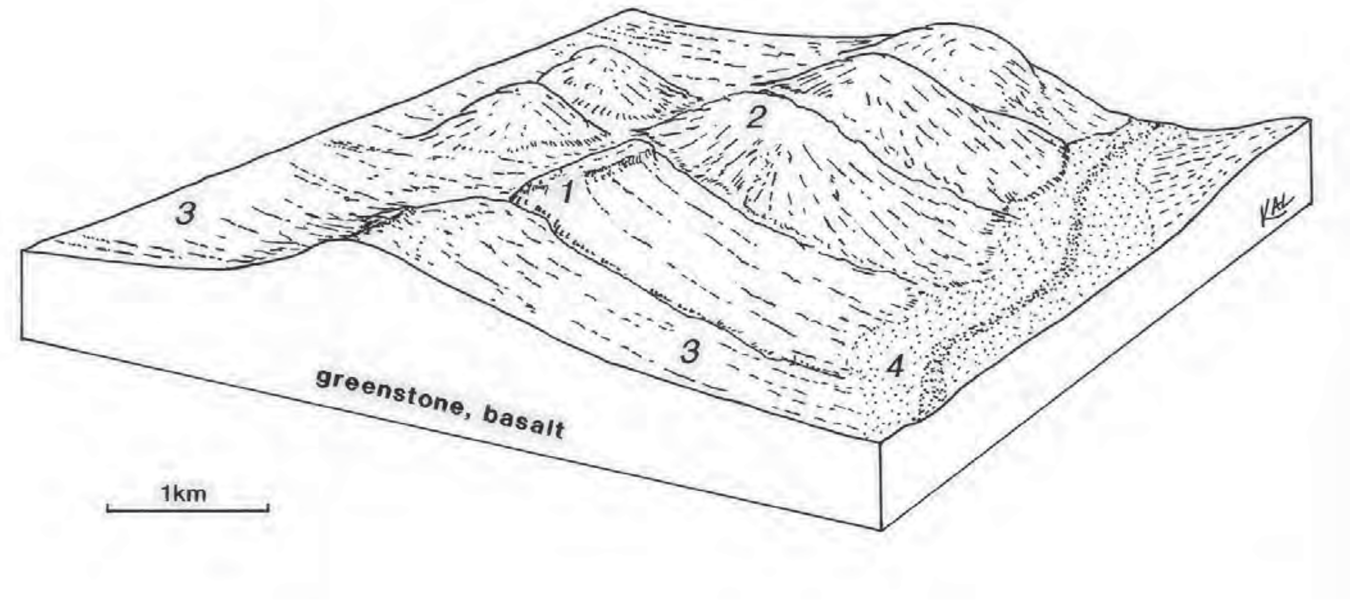
Geomorphology: Erosional surfaces; low undulating hills and ridges with very gently inclined footslopes and narrow generally unincised tributary drainage tracts. Relief to 50 m.

Land management: Narrow drainage tracts (unit 4) are susceptible to water erosion, particularly where perennial shrub cover has been substantially reduced and/or the soil surface is disturbed. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary. Not traversed.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Ridge	–	–
2	Hill	–	–
3	Footslope	–	–
4	Narrow drainage tracts	–	–
	Total	0	0

Lawrence land system

Unit area (%)		Landform	Soil	Vegetation
1.	10%	**Ridges** – low banded ironstone ridges (<50 m relief) with mantles of angular platy shaped pebbles on upper slopes.	Stony soils (1).	Scattered (10-20% PFC) acacia tall shrublands (SIMS or GHAS).
2.	50%	**Hills** – often linearly arranged low rounded hills and rises of greenstone, relief to 30 m. Hillslopes very gently to gently inclined with mantles of abundant greenstone and ironstone pebbles and cobbles.	Stony soils and shallow stony red earths (1, 5b).	Generally scattered (10-20% PFC) acacia tall shrublands on hillcrests (GHAS) and scattered *Maireana sedifolia* (pearl bluebush) low shrublands on slopes, locally with a dominant tree (eucalypt) or tall shrub (acacia) stratum.
3.	30%	**Footslopes** – very gently inclined lower slopes with mantles of abundant greenstone and ironstone pebbles and cobbles.	Stony soils and shallow stony red earths (1, 5b) with some shallow duplex on greenstone (7b).	Generally scattered to moderately close (10-30% PFC) eucalypt woodlands with prominent halophytic understoreys including *Atriplex vesicaria* (bladder saltbush) (PECW).
4.	10%	**Narrow drainage tracts** – generally level unincised concentrated flow zones in lowest areas.	Variable depth clays (9a, 9b).	Scattered to moderately close (10-30% PFC) *Atriplex* (saltbush) low shrublands frequently with prominent eucalypts (PECW).

MARLOW LAND SYSTEM (137 km^2, 0.1% of the survey area)

Alluvial plains with numerous small drainage foci supporting acacia and melaleuca shrublands with non-halophytic and halophytic undershrubs.

Land type: 15

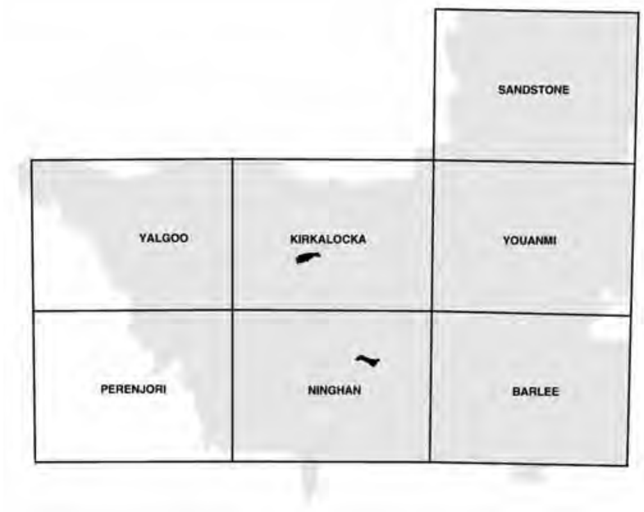
Geology: Quaternary alluvium and minor aeolian deposits.

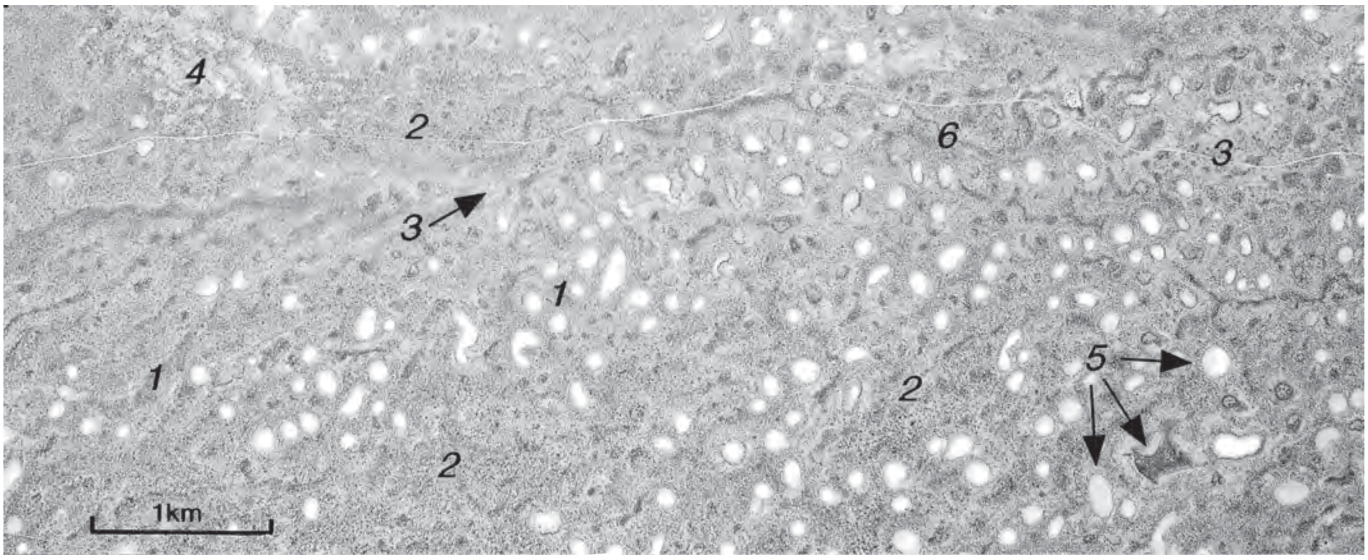
Geomorphology: Depositional surfaces; plains with numerous small discrete drainage foci, scattered sandy banks elevated up to 2 m above surrounding plains and narrow, unincised sinuous drainage tracts. Overall relief <5 m.

Land management: The system supports low shrubs which are attractive to grazing animals and, under uncontrolled stocking, the vegetation is prone to degradation. Soils generally have low susceptibility to erosion except those units with duplex soils.

Traverse condition summary (35 assessments):
Vegetation – good 3%; fair 34%; poor 46%; very poor 17%.
Soil erosion – nil 83%; slight 3%; minor 8%; moderate 3%; severe 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank	3	1
2	Hardpan plain	18	2
3	Alluvial plain	1	2
4	Calcrete plain	2	–
5	Drainage focus	1	2
6	Drainage tract	11	2
	Total	36 *	9

* 1 traverse point not assessed for condition.

Marlow land system

Unit area (%)		Landform	Soil	Vegetation
1.	15%	**Sandy banks** – scattered irregular patches on units 2 & 3 or fringing unit 4, usually <100 m in extent and to 2 m higher than surrounding plains.	Deep red clayey sands (3a).	Moderately close (20-30% PFC) *Acacia ramulosa* (bowgada) tall shrublands with low shrubs such as *Eremophila forrestii* (Wilcox bush) and sparse wanderrie grasses (WABS).
2.	50%	**Hardpan plains** – nearly level loamy and sandy plains subject to sheet flow.	Shallow red clayey sands on hardpan (2d) or shallow hardpan loams and red earths (5d, 5c).	Moderately close (20-30% PFC) *Acacia ramulosa, A. acuminata* subsp. *burkittii* (fine-leaf jam) and *A. aneura* (mulga) tall shrublands with non-halophytic and halophytic undershrubs (HCAS, less frequently HMCS).
3.	10%	**Alluvial plains** – very gently inclined plains receiving more concentrated run-on than the hardpan plains (unit 2) in which it occurs as a mosaic.	Shallow duplex on calcrete or shallow clays on hardpan (7c, 9a).	Moderately close (20-30% PFC) acacia tall shrubland with halophytic undershrubs (DACS) or scattered (10-20% PFC) low shrublands of *Maireana pyramidata* (sago bush) and *Atriplex* spp. (saltbush) (PSAS).
4.	5%	**Calcrete plains** – plains with mantles of calcrete rubble, marginally raised (0.5 m) above adjacent units.	Shallow calcareous loams or red clayey sands on calcrete (5a, 2c).	Scattered to moderately close (10-30% PFC) *Acacia acuminata* subsp. *burkittii* and other *Acacia* spp. tall shrublands (JAMS).
5.	10%	**Drainage foci** – numerous small (mostly <300 m in diameter) foci and swampy depressions scattered over units 2 & 3.	Shallow to deep clays on hardpan (9a, 9b).	Moderately close (20-30% PFC) melaleuca tall shrublands (MESS) or *Acacia tetragonophylla* (curara) tall shrublands with an *Eriachne flaccida* (claypan grass) understorey (ACGU); claypans unvegetated.
6.	10%	**Drainage tracts** – mostly <500 m wide unchannelled tracts slightly lower than adjacent units.	Shallow to deep clays on calcrete or hardpan (9a, 9b).	Scattered to close (10-30% PFC) melaleuca or *Acacia tetragonophylla* tall shrublands with sparse grasses (DRAS, ACGU).

MARMION LAND SYSTEM (4,150 km^2, 4.4% of the survey area)

(after Pringle *et al.* 1994)

Gently undulating sandplains with mixed shrublands and hummock grasslands.

Land type: 10

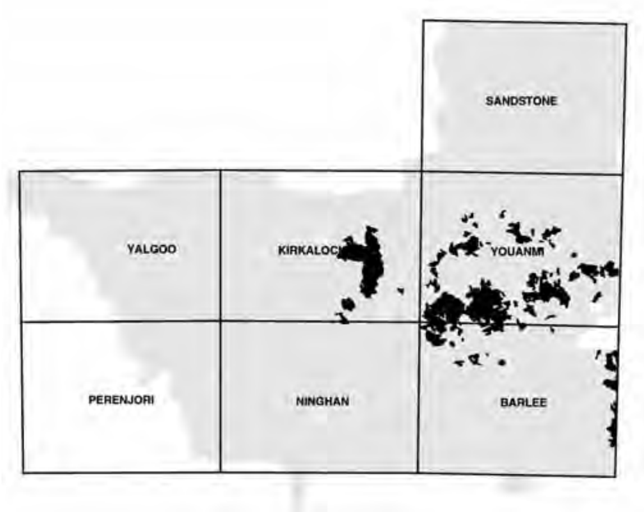
Geology: Quaternary sands with minor alluvium and Archaean granite.

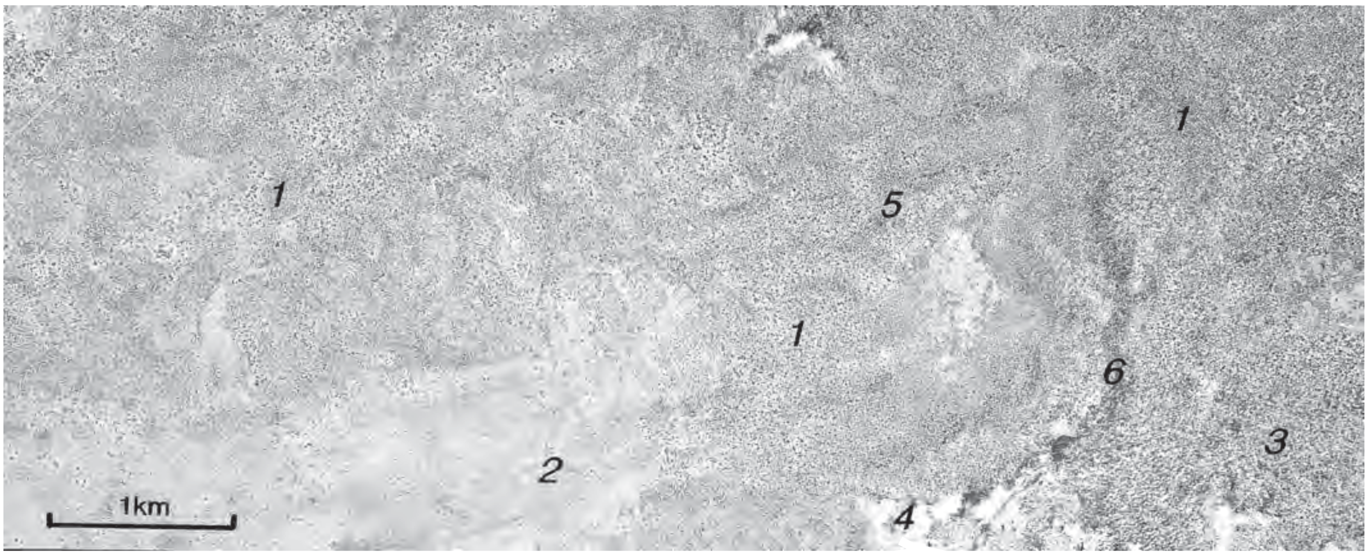
Geomorphology: Depositional surfaces; level to gently undulating sandplains with surface drainage features confined to areas fringing occasional exposures of granite.

Land management: Spinifex hummock grasslands are susceptible to wildfires which can damage capital improvements such as fences and adjacent, less fire-adapted plant communities. The maintenance of fire breaks in this country will help control and localise outbreaks of fire. Sands may become susceptible to wind erosion immediately following fire but generally stabilise quickly with the emergence of regrowth following rains.

Traverse condition summary (120 assessments):
Vegetation – good 84%; fair 13%; poor 3%; very poor 0%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sand sheet	76	3
2	Gravelly sand sheet	26	2
3	Loamy plain	10	1
4	Stripped surface	4	–
5	Dune	4	1
6	Narrow drainage tract	2	–
	Other	2	–
	Total	124 *	7

* 4 traverse points not assessed for condition.

Marmion land system

	Unit area (%)	Landform	Soil	Vegetation
1.	60%	**Sand sheets** – level to gently undulating sandplain.	Deep red clayey sands (3a).	*Triodia basedowii* (hard spinifex) hummock grasslands with mallee eucalypt or acacia overstoreys (SASP) or scattered to moderately close (10-30% PFC) *Acacia coolgardiensis* (sugar brother) tall shrublands with occasional mallees, and spinifex (SACS).
2.	20%	**Gravelly sand sheets** – gently undulating sand sheet with mantles of ironstone gravel.	Shallow red clayey sands with ferruginous gravel (2b).	Moderately close low or mid height myrtaceous shrublands (LSHE) and moderately close (20-30% PFC) acacia tall shrublands (SACS).
3.	10%	**Loamy plains** – level plains receiving diffuse run-on from stripped surfaces (unit 4).	Deep red clayey sands (3a).	Moderately close (20-30% PFC) acacia tall shrublands and sparse wanderrie grasses in more open shrublands (SACS, SWGS).
4.	4%	**Stripped surfaces** – exfoliating low (<5 m) outcrops of granite with narrow fringing plains, occasional duricrusted surfaces.	Pockets of shallow coarse red clayey sands (2a).	Very scattered (2.5-10% PFC) *Acacia aneura* (mulga) and *A. quadrimarginea* (granite wattle) tall shrublands (SGRS) or scattered (10-20% PFC mixed myrtaceous shrublands.
5.	3%	**Dunes** – occasional low (<10 m) broad dunes occurring in the more extensive areas of sand sheet (unit 1).	Deep red sands (3c).	Variable, often moderately close (20-30% PFC) tall shrublands consisting of acacias, mallees, *Callitris glaucophylla* (native pine), *Grevillea* and *Hakea* spp. with a heath stratum and spinifex (SDSH).
6.	1%	**Narrow drainage tracts** – occasional narrow (<500 m wide), linear zones receiving concentrated run-on from adjacent granite systems.	Sandy red earths (4).	Close (30-50% PFC) *A. aneura* tall shrublands, understorey may contain heath species (DRAS).

MELALEUCA LAND SYSTEM (129 km^2, 0.1% of the survey area)

(after Pringle *et al.* 1994)

Sandy tracts and drainage foci, supporting acacia shrublands.

Land type: 18

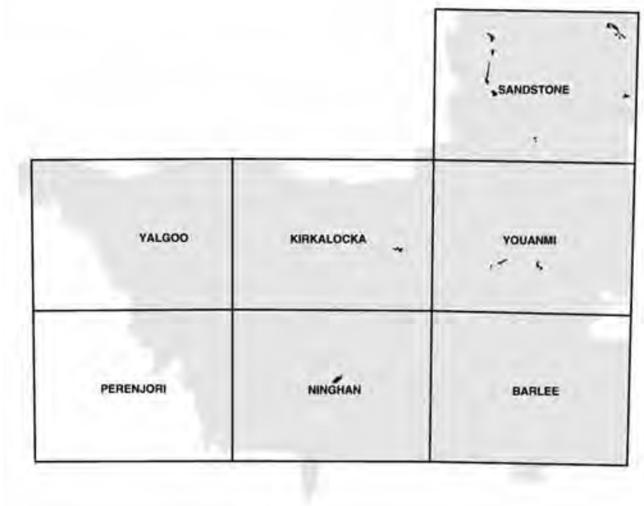
Geology: Tertiary calcrete, Quaternary sand and minor alluvium.

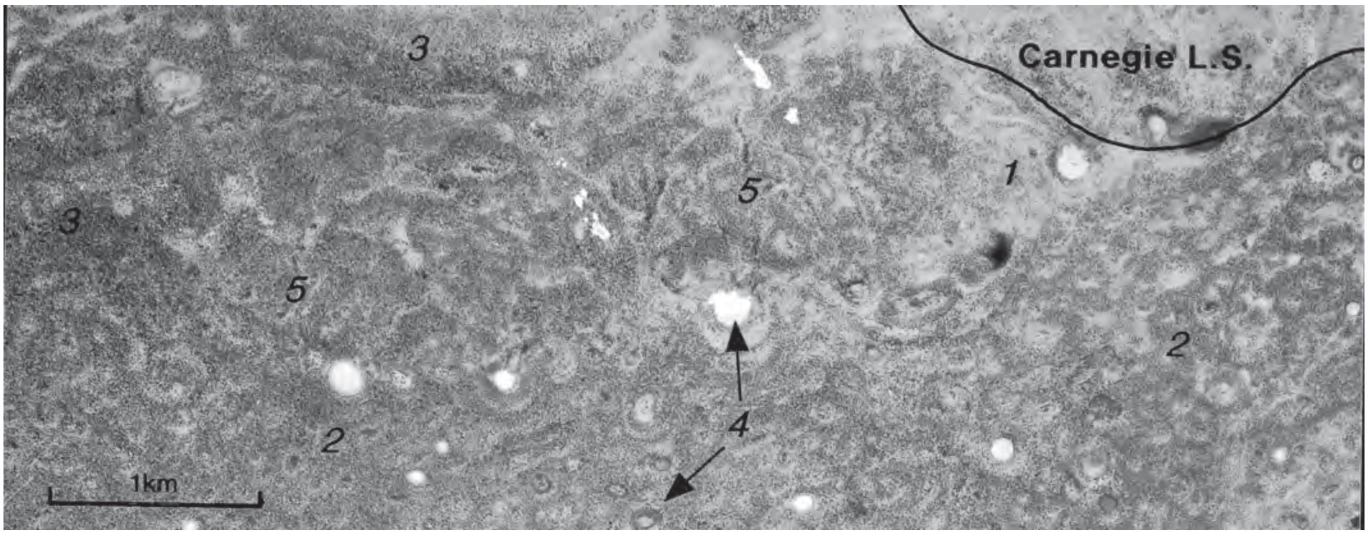
Geomorphology: Depositional surfaces; level to gently undulating sandy tracts with swamps and claypans, occasional level to very gently inclined plains with calcrete rubble.

Land management: This system is generally not susceptible to soil erosion.

Traverse condition summary (13 assessments):
Vegetation – good 23%; fair 39%; poor 38%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Calcrete plain	1	2
2	Loamy plain	7	–
3	Sand sheet	3	4
4	Drainage focus	2	–
5	Drainage line	1	1
	Total	14 *	7

* 1 traverse points not assessed for condition.

Melaleuca land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Calcrete plains** – level to very gently inclined plains with 0.5 to 1 m relief, calcrete rubble and outcrop.	Shallow red clayey sands or duplex on calcrete (2c, 7c).	Moderately close (20-30% PFC) *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) tall shrublands (JAMS) or moderately close (20-30% PFC) melaleuca mid to tall shrublands (MESS).
2.	50%	**Loamy plains** – level plains and irregular sandy banks.	Sandy red earths (4).	Scattered to moderately close (10-30% PFC) *Acacia aneura* (mulga) and *A. ramulosa* (bowgada) tall shrublands occasionally with sparse wanderrie grasses (MUBW, WABS).
3.	20%	**Sand sheet** – sandy tracts on margins of system.	Deep red clayey sands or red clayey sands on hardpan (3a).	Spinifex hummock grasslands with scattered acacias and mallees (SASP) or moderately close (20-30% PFC) acacia tall shrublands (SACS).
4.	15%	**Drainage foc**i – slight depressions receiving run-on, ephemerally inundated swamps and claypans, to 500 m in extent.	Variable depth clays (9a, 9b).	Moderately close to close (20-50% PFC) *A. aneura-Melaleuca* spp. shrublands occasionally with claypan grasses in depressions and fringing unvegetated claypans (DRAS, ACGU, MESS); scattered (10-20% PFC) *Muehlenbeckia cunninghamii* (lignum) shrublands on swamps (LISW).
5.	5%	**Drainage lines** – poorly defined narrow unchannelled tracts receiving concentrated flow.	Deep red earths or shallow duplex on hardpan (6a, 7c).	Moderately close (20-30% PFC) *A aneura* tall shrublands (DRAS) or moderately close (20-30% PFC) *Acacia masliniana* (spiny snakewood) tall shrublands with halophytic low shrubs (ASWS).

MERBLA LAND SYSTEM (360 km², 0.4% of the survey area)

(after Curry *et al.* 1994)

Alluvial plains with clayey soils and partly gilgai (crabhole) surfaces supporting halophytic low shrublands and patchy perennial grasses.

Land type: 17

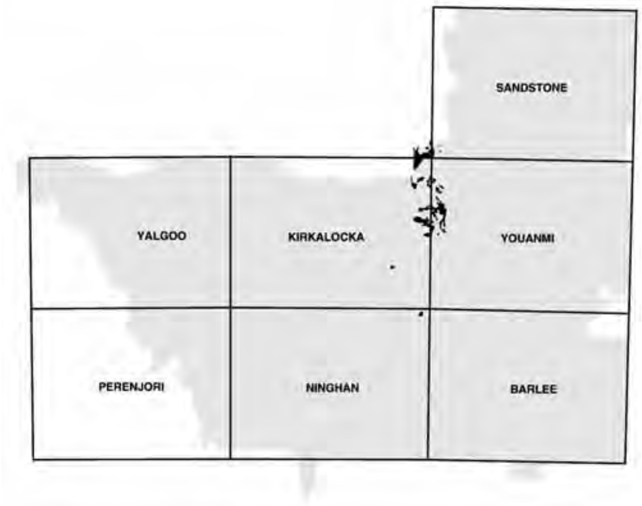
Geology: Quaternary alluvium and colluvium derived from Archaean gabbro.

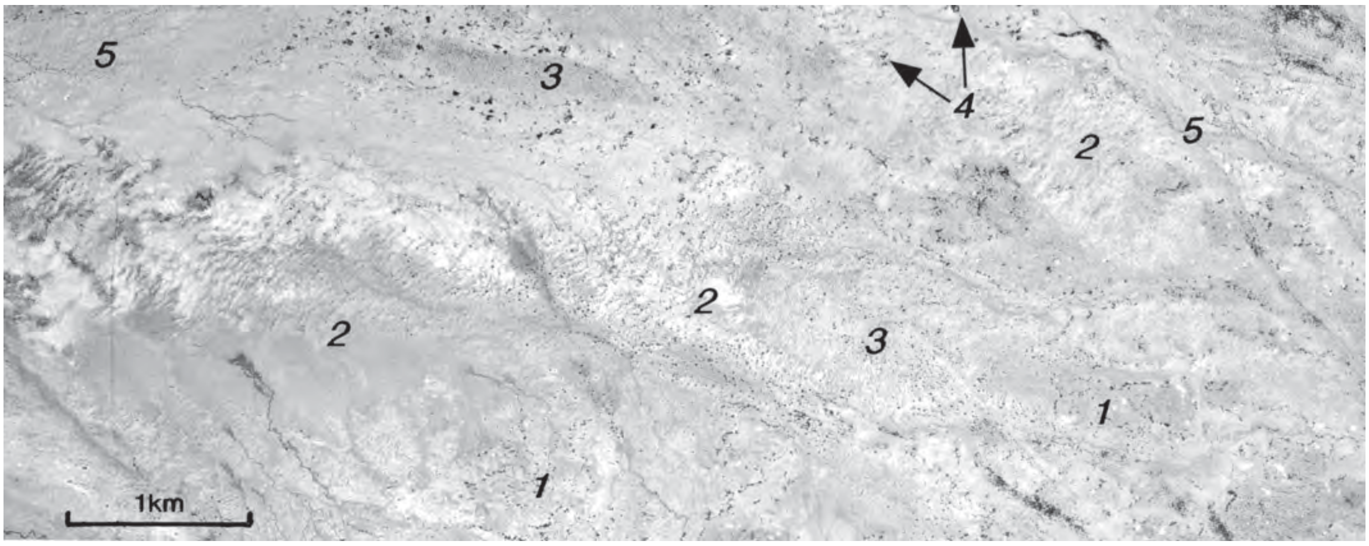
Geomorphology: Depositional surfaces; alluvial plains with gilgai and non-gilgai surfaces interconnected by mainly sluggish, meandering tributary drainage tracts; also slightly more elevated plains with stone mantles. Relief is mostly <2 m.

Land management: This system supports vegetation which is highly attractive to grazing animals and is likely to become degraded if grazing control is inadequate; some areas are moderately susceptible to accelerated erosion if degraded especially units 3 and 5 and are prone to invasion by introduced weeds such as saffron thistle (Carthamus lanatus).

Traverse condition summary (65 assessments):
Vegetation – good 19%; fair 29%; poor 34%; very poor 18%.
Soil erosion – nil 72%; slight 3%; minor 9%; moderate 14%; extreme 2%.

Area mapped as sde: 12.5 km² (3.5% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Saline stony plain	7	2
2	Gilgai plain	18	7
3	Alluvial plain	28	7
4	Drainage foci	1	1
5	Drainage tract	12	2
	Other	4	–
	Total	70 *	19

* 5 traverse points not assessed for condition.

Merbla land system

Unit area (%)	Landform	Soil	Vegetation
1. 10%	**Saline stony plains** – level plains slightly elevated above units 2 and 3, mantles of variable density quartz pebbles.	Deep clays, deep duplex or deep red earths over parent material or hardpan (9b, 8, 6a).	Very scattered to scattered 2.5-20% PFC) low shrublands of *Maireana pyramidata* (sago bush) (SBMS, PSAS).
2. 60%	**Gilgai plains** – somewhat saline level plains extending for 5 or 6 km with patchy gilgai micro-relief, occasionally with mantles of ironstone gravel.	Dark red cracking clays mostly >1 m deep (10).	Isolated to scattered (<20% PFC) low shrublands of *M. pyramidata, Atriplex nummularia* (old man saltbush) and patchy perennial grasses (GGLS, PSAS), also dense annual herbfields.
3. 25%	**Alluvial plains** – partly saline, level alluvial plains, subject to flooding; sometimes with mantles of sparse ironstone and quartz pebbles and scalded and eroded surfaces.	Deep duplex or deep clays (8, 9b).	Isolated to scattered (<20% PFC) low shrublands mainly of *M. pyramidata* (PSAS, PXHS), also annual herbfields.
4. <1 %	**Drainage foc**i – small (mostly <50 m in extent) discrete drainage foci and occasional larger swamps scattered over units 3 and 5.	Deep clays (9b).	Moderately close (20-30% PFC) acacia tall shrublands with mixed halophytic and non-halophytic low shrubs (DRAS, DMCS), occasionally *Eragrostis australasica* (cane grass) grasslands (CGSW).
5. 5%	**Drainage tracts** – sluggish drainage tracts usually <400 m wide passing through units 2 and 3, with meandering channels up to 20 m wide draining mainly into unchannelled internal drainage zones.	Deep red clays (9b) with juvenile types in drainage channels (12).	Scattered to moderately close (10-20% PFC) acacia shrublands with scattered halophytic low shrubs and perennial grasses on channel margins (DMCS), also low halophytic shrublands (PXHS).

MILEURA LAND SYSTEM (708 km^2, 0.7% of the survey area)

(after Mabbutt *et al.* 1963)

Calcrete platforms and saline alluvial plains supporting halophytic shrublands.

Land type: 18

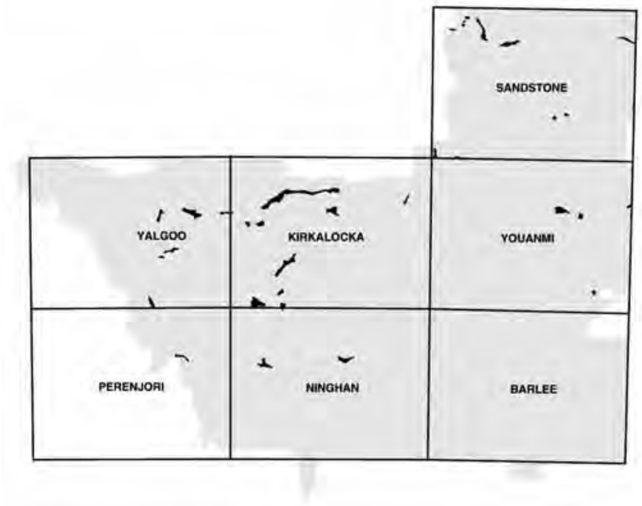
Geology: Tertiary calcrete and Quaternary alluvium.

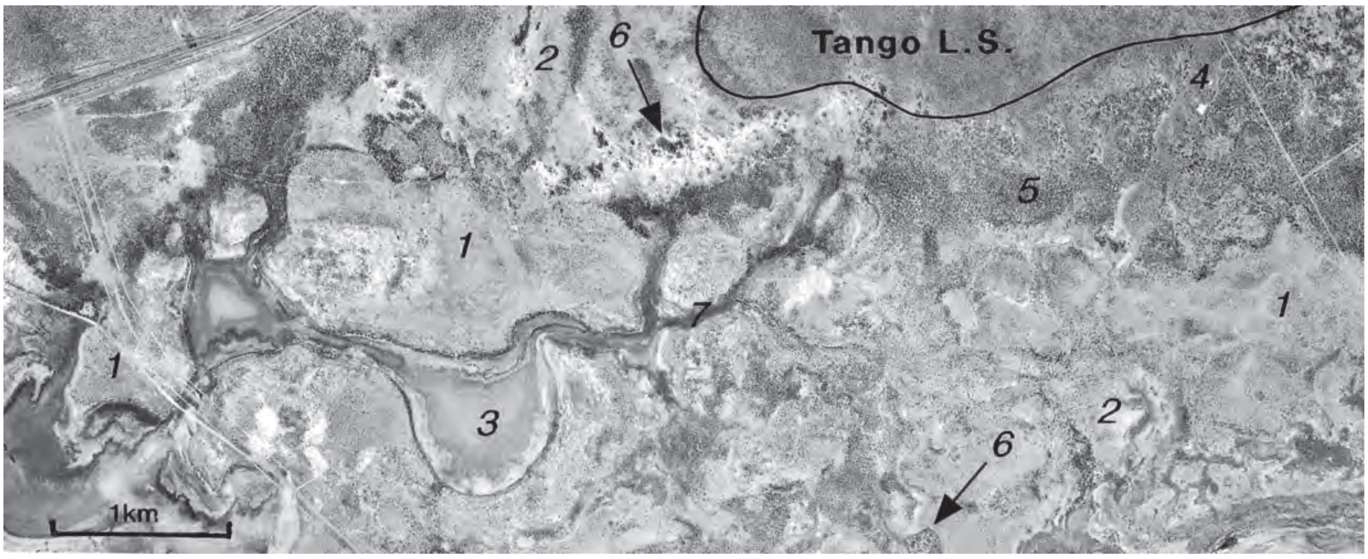
Geomorphology: Depositional surfaces; calcrete valley fills; a mosaic of calcrete platforms and alluvial plains, occasional sandy banks and usually unincised drainage tracts.

Land management: Alluvial plains (unit 2) are moderately susceptible to water erosion, particularly where perennial shrub cover has been substantially reduced or the soil surface is disturbed. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (199 assessments):
Vegetation – good 36%; fair 30%; poor 25%; very poor 9%.
Soil erosion – nil 86%; slight 3%; minor 7%; moderate 4%.

Area mapped as sde: 0.1 km^2 (0.02% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Calcrete platform/calcrete plain	49	10
2	Alluvial plain	87	9
3	Saline plain	8	3
4	Hardpan plain	23	2
5	Sandy bank	9	1
6	Drainage focus	7	6
7	Drainage tract	9	3
	Other	2	–
	Total	194 *	34

* 5 traverse points not assessed for condition.

Mileura land system

Unit	area (%)	Landform	Soil	Vegetation
1.	30%	**Calcrete platforms and plains** – platforms (1-3 m relief) and plains to 3 or 4 km in extent, with mantles of calcrete rubble.	Shallow calcareous loams on calcrete (5a).	Variable: scattered to moderately close (10-30% PFC) eucalypt woodlands, (CAPW), scattered (10-20% PFC) *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) tall shrublands (JAMS) or scattered (10-20% PFC) *Atriplex bunburyana* (silver saltbush) low shrublands (SSAS).
2.	40%	**Alluvial plains** – level to very gently inclined plains between platforms (unit 1) with occasional incised channels in lowest areas.	Variable depth duplex and clays (7c, 7d, 9a, 9b), with shallow hardpan loams and shallow red clayey sands on calcrete or hardpan (5d, 2c).	Scattered (10-20% PFC) halophytic low shrublands, (PXHS), occasionally with *Atriplex bunburyana* dominant (SSAS), also scattered *Acacia eremaea* (snakewood) tall shrubland with halophytic undershrubs (ASWS).
3.	10%	**Saline plains** – level plains slightly lower than units 2 & 4, subject to episodic inundation.	Deep and shallow clays on calcrete (9a, 9b).	Scattered to moderately close (10-30% PFC) *Halosarcia* spp. (samphire) low shrublands (SAMP).
4.	10%	**Hardpan plains** – nearly level plains subject to sheet flow.	Shallow hardpan loams (5d).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with halophytic and non-halophytic low shrubs (HMCS, HPMS).
5.	3%	**Sandy banks** – low banks to 1 m relief, mostly on units 3 and 4.	Deep red clayey sands on calcrete or hardpan (3a).	Scattered to moderately close (10-30% PFC) tall and low shrublands with *Acacia aneura* (mulga) with halophytic and non-halophytic low shrubs and sparse wanderrie grass (SBLS, WABS).
6.	2%	**Drainage foci** – foci and swampy depressions up to 200 m in diameter.	Deep clays or red earths (9b, 6a) and shallow clays on calcrete (9a).	Scattered to closed (>10% PFC) variable shrublands or grassy shrublands dominated by *Melaleuca* spp. (paperbark), *A. aneura, A. tetragonophylla* (curara) or *Muehlenbeckia cunninghamii* (lignum) (MESS, ACGU, DMCS, LISW).
7.	5%	**Drainage tracts** – linear zones in unit 4 or passing through units 1 and 2 receiving more concentrated flow, rarely incised.	Shallow calcareous loams (5a), deep red earths and duplex soils on hardpan or calcrete (6a, 7c).	Scattered to close (10-50% PFC) acacia and melaleuca tall shrublands (DMCS, DRAS, MESS).

MONITOR LAND SYSTEM (66 km^2, 0.1% of the survey area)

(after Pringle *et al.* 1994)

Distributary alluvial fans and wash plains supporting mulga-halophytic shrublands.

Land type: 15

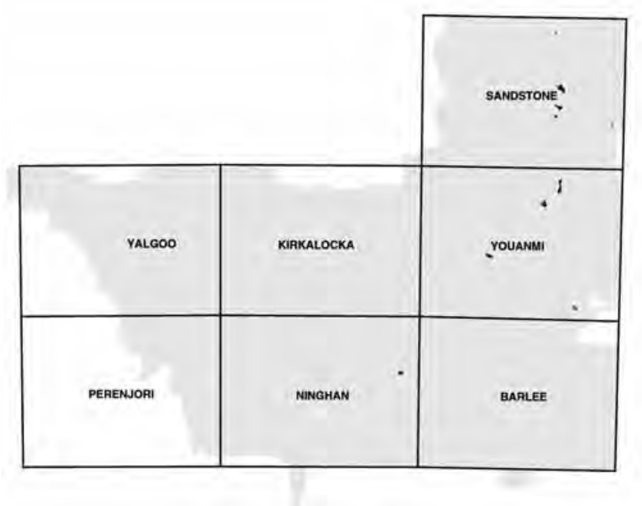
Geology: Quaternary alluvium.

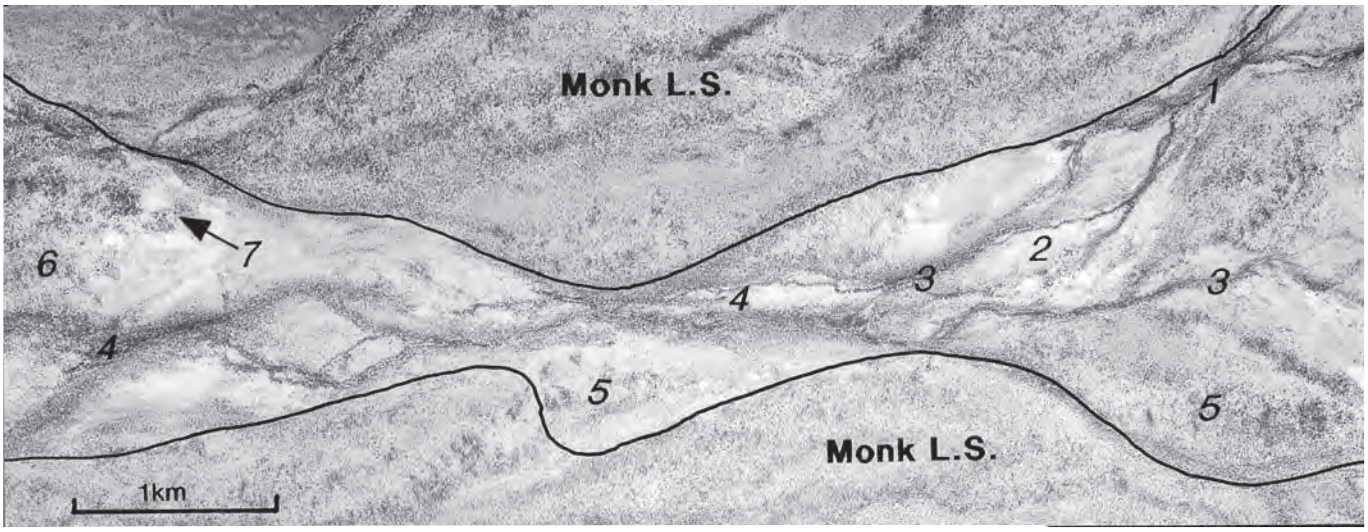
Geomorphology: Depositional surfaces; extensive distributary alluvial fans receiving run-on from dispersing channels emerging from greenstone hills, drainage tracts receiving concentrated flow and alluvial plains subject to more dispersed sheet flow.

Land management: Alluvial fans (unit 2) and drainage tracts (units 3 and 4) are highly susceptible to soil erosion and hardpan plains (unit 5) are slightly susceptible. Water starvation and consequent loss of vigour in vegetation is likely to occur downslope of impedances to natural flows of water. The vegetation is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure. Proportional to its area, this is the most degraded land system in the survey area.

Traverse condition summary (12 assessments):
Vegetation – good 0%; fair 8%. poor 42%; very poor 50%.
Soil erosion – nil 50%; minor 17%; moderate 17%; severe 8%; extreme 8%.

Area mapped as sde: 14.1 km^2 (21.5% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Channel	–	–
2	Alluvial fan	3	1
3	Drainage line	3	–
4	Drainage floor	3	1
5	Hardpan plain	8	1
6	Loamy plain	2	–
7	Drainage focus	1	–
	Other	1	–
	Total	21 *	3

* 9 traverse points not assessed for condition.

Monitor land system

Unit	area (%)	Landform	Soil	Vegetation
1.	<1%	**Channels** – incised drainage lines emerging from greenstone hills.	Juvenile deposits – coarse bedloads (12).	Fringing moderately close to close (20-50% PFC) *Acacia aneura* (mulga) tall shrublands (CBKW).
2.	15%	**Alluvial fans** – level to very gently inclined distributary plains receiving concentrated run-on.	Shallow saline duplex or red clays, on hardpan (7c, 9a).	Scattered (10-20% PFC) halophytic low shrublands (PXHS) or mulga shrublands with scattered halophytic under shrubs (HMCS).
3.	10%	**Drainage lines** – narrow flow lines receiving concentrated flow, through unit 2.	Shallow saline duplex on hardpan (7c).	Scattered (10-20% PFC) halophytic low shrublands (PXHS) or acacia tall shrublands (DRAS).
4.	15%	**Drainage floors** – broad flow zones (>500 m wide), receiving concentrated flow from units 2 and 3.	Shallow red earths or clays on hardpan (5c, 9a), or deep clays on greenstone (9b).	Moderately close to close (20-50% PFC) acacia tall shrublands (DRAS). Acacia species include *A. acuminata* subsp. *burkittii* (fine-leaf jam), *A. craspedocarpa* (hop mulga), *A. aneura* and *A. tetragonophylla* (curara).
5.	55%	**Hardpan plains** – nearly level plains with occasional groves, subject to dispersed sheet flow, may have a mantle of ironstone gravel.	Shallow hardpan loams (5c). Deep red earths in groves (6a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with halophytic and non-halophytic low shrubs (HMCS, HPMS). Close (30-50% PFC) *A. aneura* tall shrublands in groves (GRMU).
6.	5%	**Loamy plains** – isolated level tracts on hardpan plains (unit 5)	Deep red earths (6a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with wanderrie grasses (MUWA).
7.	<1%	**Drainage foci** – small irregular depressions.	Red clays on hardpan (9a, 9b).	Perennial claypan grasses with isolated (<2.5% PFC) acacia shrubs (ACGU).

MONK LAND SYSTEM (1,822 km², 1.9% of the survey area)

(after Pringle *et al.* 1994)

Hardpan plains with occasional sandy banks supporting mulga tall shrublands and wanderrie grasses.

Land type: 14

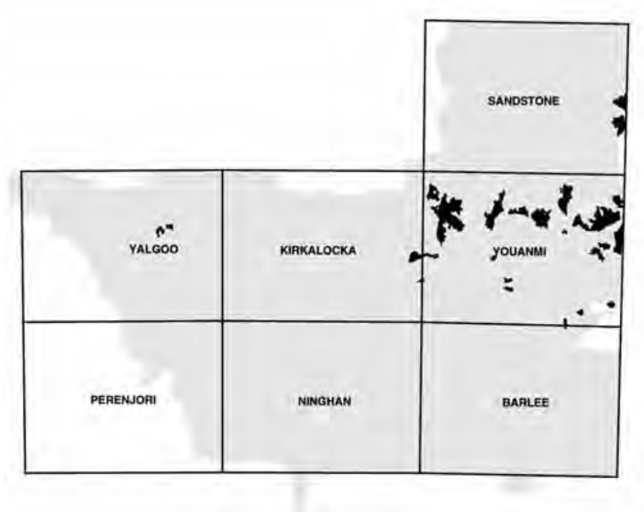
Geology: Cemented Quaternary alluvium and sand, derived mainly from granite.

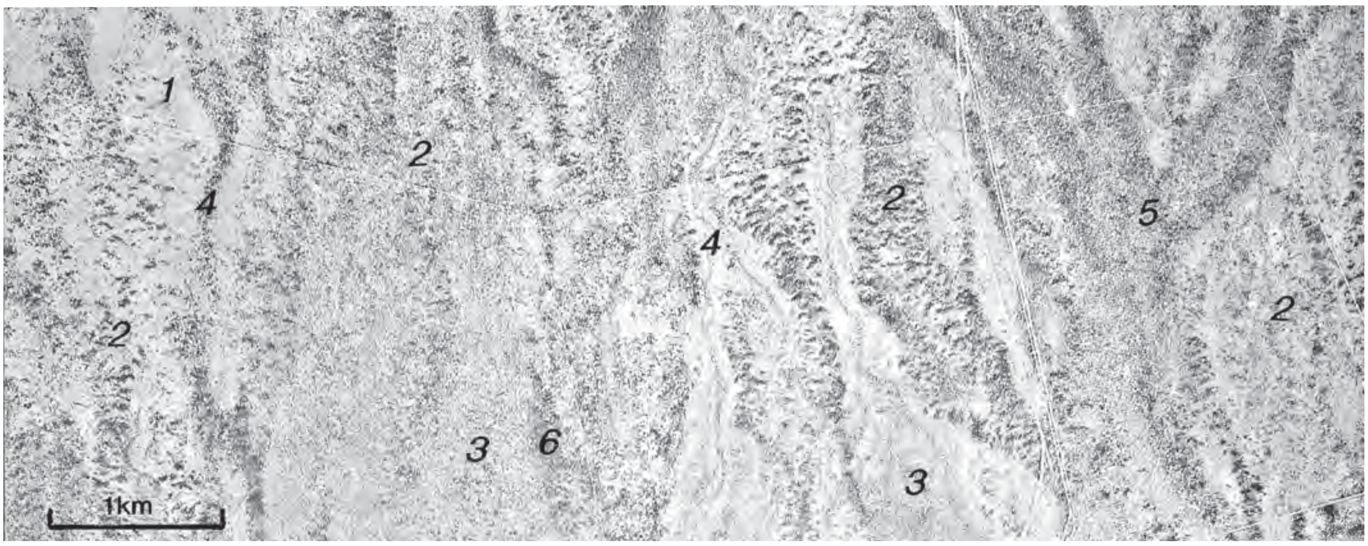
Geomorphology: Depositional surfaces; extensive, level to gently inclined plains subject to sheet flow with generally sparse sub-parallel unincised drainage zones; sandy tracts and banks in lower areas.

Land management: Drainage tracts (units 4 and 5) are mildly susceptible to water erosion, this system is susceptible to water starvation and consequent loss of vigour in vegetation if natural water flow is impeded.

Traverse condition summary (251 assessments):
Vegetation – good 24%; fair 39%; poor 28%; very poor 9%.
Soil erosion – nil 99%; minor 1%.

Area mapped as sde: 1.9 km² (0.1% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Stony hardpan plain	4	–
2	Hardpan plain	111	4
3	Loamy tract	96	2
4	Narrow drainage tract	21	2
5	Broad drainage tract	11	2
6	Sandy bank	19	1
	Other	3	–
	Total	265 *	11

* 14 traverse points not assessed for condition.

Q

Monk land system

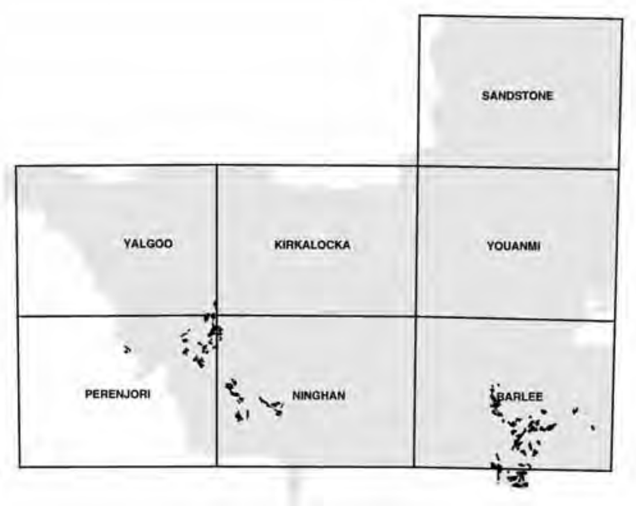
Unit	area (%)	Landform	Soil	Vegetation
1.	2%	**Stony hardpan plains** – very gently inclined plains subject to sheet flow, with mantles of quartz pebbles and stones in upper sectors.	Shallow red earths with a stony mantle, on hardpan (5c) .	Very scattered to scattered (2.5-20% PFC) *Acacia aneura* (mulga) tall shrublands (HPMS, SAES).
2.	44%	**Hardpan plains** – extensive, level to very gently inclined plains subject to sheet flow and with occasional contour-aligned arcuate drainage foci (groves).	Red earths on hardpan at variable depth (5c, 6a).	Generally scattered (10-20% PFC) *A. aneura* tall shrublands (HPMS), denser (>30% PFC) in groves (GRMU).
3.	40%	**Loamy tracts** – level plains receiving diffuse run-on.	Sandy red earths or deep red earths (4, 6a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with *Monachather paradoxa* (broad-leaved wanderrie), *Thyridolepis multiculmis* (soft wanderrie) and *Eragrostis eriopoda* (woolly butt) grasses (PLMS, MUBW, MUWA).
4.	6%	**Narrow drainage tracts** – widely spaced, narrow (<50 m wide) sub-parallel and unchannelled concentrated drainage tracts on units 1 and 2.	Shallow red earths on hardpan or deep red earths (5c, 6a).	Moderately close (20-30% PFC) *A. aneura* or *A. craspedocarpa* (hop mulga) tall shrublands (DRAS).
5.	3%	**Broad drainage tracts** – unchannelled concentrated drainage zones up to 2 km wide.	Shallow red earths or shallow hardpan loams (5c, 5d).	As for unit 4.
6.	5%	**Sandy banks** – irregular low (typically <30 cm relief) sandy banks usually found in lower sectors.	Deep sandy red earths (4).	Scattered (10-20% PFC) acacia tall shrublands with *Monachather paradoxa* (WABS).

MORIARTY LAND SYSTEM (825 km[2], 0.9% of the survey area)

(after Pringle *et al.* 1994)

Low greenstone rises and stony plains supporting halophytic and acacia shrublands with patchy eucalypt overstoreys.

Land type: 8



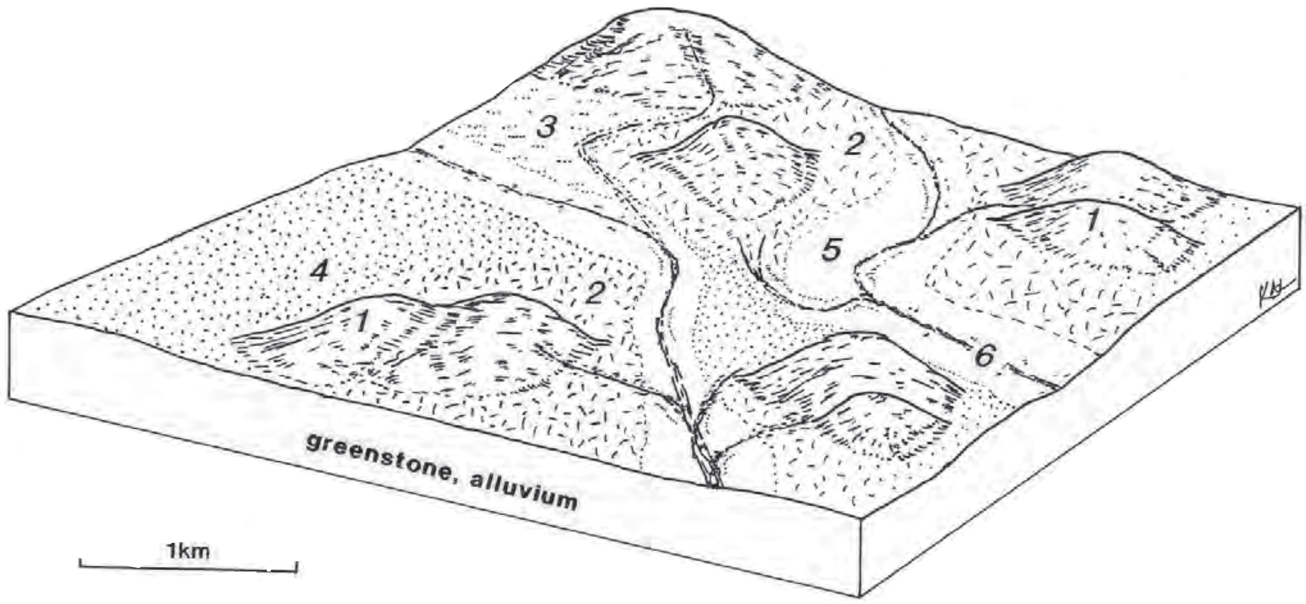
Geology: Archaean greenstone, minor granite, Tertiary ferruginous duricrust, Quaternary colluvium and alluvium.

Geomorphology: Mainly erosional surfaces; low rises to 20 m relief, locally with ferruginous duricrust, gently undulating lower plains with pebble mantles and level to very gently inclined alluvial plains; poorly defined, sparse drainage patterns.

Land management: Slopes of low rises without protective stone mantles (unit 1), alluvial plains (unit 4) and narrow drainage tracts (unit 5) are moderately susceptible to water erosion, particularly if perennial shrub cover is substantially reduced or the soil surface is disturbed. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (127 assessments):
Vegetation – good 42%; fair 35%; poor 18%; very poor 5%.
Soil erosion – nil 99%; minor 1%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1	Low rise	7	4
2	Stony plain	28	2
3.	Gravelly saline alluvial plain	13	4
4	Gravelly plain	36	5
5	Alluvial plain	39	9
6	Drainage tract	5	1
	Other	1	1
	Total	129 *	26

* 2 traverse points not assessed for condition.

Moriarty land system

Unit	area (%)	Landform	Soil	Vegetation
1.	15%	**Low rises** – low rises (usually <10 m relief) on greenstone, often with ferruginous duricrust and mixed mantles of many to abundant greenstone, quartz and ironstone pebbles and cobbles.	Shallow stony red earths (5b); calcareous loams and stony soils on calcrete veneer over greenstone (5a, 1).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with patchy emergent eucalypts and *Casuarina pauper* (black oak) over mainly non-halophytic low shrubs (GHMW, SIMS, LACS).
2.	20%	**Stony plains** – gently undulating plains with mantles of many to abundant quartz, ironstone and locally calcrete pebbles and cobbles.	Deep calcareous red earths and shallow red earths on greenstone (6b, 5c).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with occasional eucalypts and *C. pauper* trees mostly over non-halophytic shrubs (SIMS, less frequently PECW, CCAS).
3.	10%	**Gravelly saline alluvial plains** – level to gently undulating with mantles of many to abundant quartz and ironstone pebbles.	Shallow clays (9a) and shallow duplex on greenstone (7b).	Scattered (10-20% PFC) eucalypt woodlands with halophytic low shrubs (PECW).
4.	25%	**Gravelly plains** – level to gently undulating plains with variable mantles of ironstone gravel and occasional calcrete rubble.	Shallow red clayey sands with ferruginous gravel or shallow red earths on greenstone (2b, 5c).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (LACS), occasionally with patchy eucalypts.
5.	25%	**Alluvial plains** – level to very gently inclined plains with mantles of few quartz and ironstone pebbles, occasionally with gilgai micro-relief.	Deep clays and red earths on greenstone (9b, 5c). Deep duplex and cracking clays on gilgais (8, 10).	Very scattered to moderately close (2.5-30% PFC) eucalypt woodlands with *Atriplex bunburyana* (silver saltbush) and other halophytic low shrubs or shrublands of acacia and *Atriplex* spp. (PECW, SSAS or BLSS). Also some eucalypt acacia woodlands with non-halophytic low shrubs (PYAW).
6.	5%	**Drainage tracts** – unchannelled central drainage tracts to 400 m wide receiving concentrated run-on; minor rills and gutters.	Shallow duplex and deep red earths on greenstone (7b, 6a).	Scattered (10-20% PFC) halophytic low shrublands, often dominated by *Atriplex* spp. (saltbush) with eucalypt overstoreys (SSAS, PECW), also moderately close (20-30% PFC) eucalypt woodlands and acacia tall shrublands (PYAW).

MULLINE LAND SYSTEM (78 km², 0.1% of the survey area)

(after Pringle *et al.* 1994)

Greenstone hills supporting acacia shrublands and eucalypt woodlands.

Land type: 1

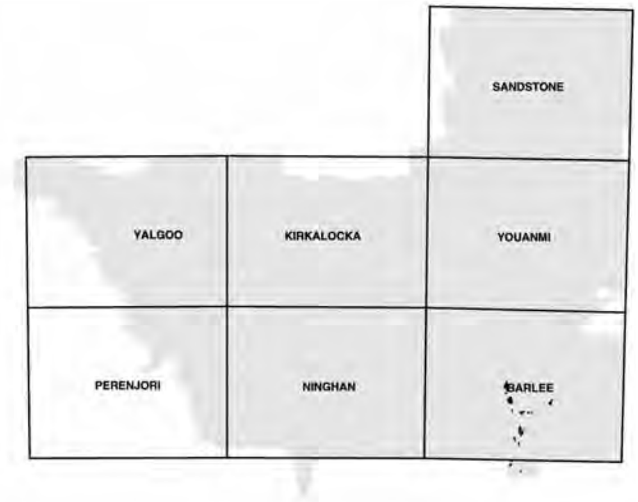
Geology: Archaean greenstones and basalt, Quaternary colluvium, eluvium and alluvium.

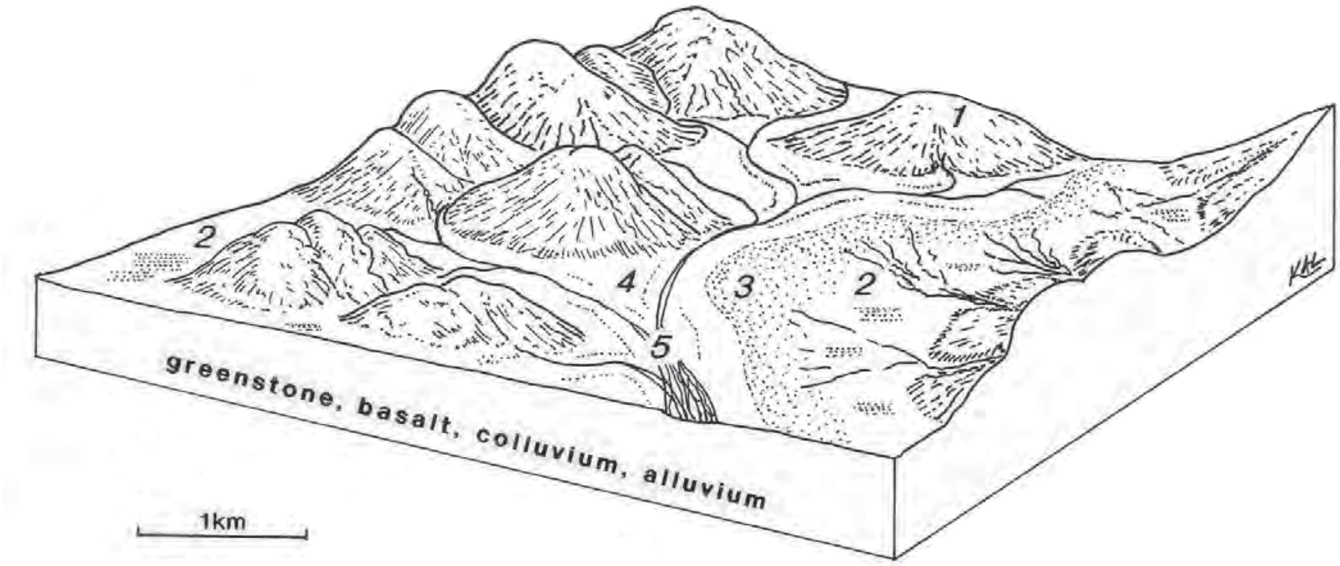
Geomorphology: Erosional surfaces; low hills (relief to 40 m) with gently inclined slopes and stony mantles; short lower plains with mantles of fine ironstone gravel and narrow drainage tracts receiving concentrated run-on.

Land management: Narrow drainage tracts (unit 5) and alluvial plains (unit 4) are moderately susceptible to water erosion, particularly where perennial shrub cover is substantially reduced or the soil surface is disturbed.

Traverse condition summary (12 assessments):
Vegetation – good 8%; fair 50%; poor 34%; very poor 8%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hill	5	2
2	Stony plain	7	–
3	Gravelly plain	1	–
4	Alluvial plain	1	1
5	Narrow drainage tract	3	1
	Total	17 *	4

* 5 traverse points not assessed for condition.

Mulline land system

Unit	area (%)	Landform	Soil	Vegetation
1.	45%	**Hills** – low hills (to 40 m relief) and footslopes with mantles of abundant greenstone and ironstone pebbles and cobbles.	Shallow stony red earths (5b), shallow clays and stony soils (9a, 1).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with patchy eucalypt and *Casuarina pauper* (black oak) trees, mostly non-halophytic understoreys (GHMW, SIMS).
2.	25%	**Stony plains** – short very gently inclined plains with pebble mantles below greenstone hills (unit 1).	Shallow red earths on greenstone, locally calcareous (5c).	Scattered (10-20% PFC) acacia tall shrublands, locally with eucalypt or *C. pauper* trees (SIMS, CCAS), rarely with halophytic low shrubs (PECW).
3.	10%	**Gravelly plains** – level to very gently inclined plains with mantles of fine ironstone gravel, locally receiving diffuse run-on.	Shallow red clayey sands with ferruginous mantle or red earths on greenstone (2d, 5c).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (mainly SACS, locally LHMS).
4.	5%	**Alluvial plains** – occasional level to very gently inclined tracts with mantles of sparse quartz and ironstone pebbles.	Deep red clays, or shallow duplex on greenstone (9b, 7b).	Scattered (10-20% PFC) halophytic low shrublands, frequently with eucalypt overstoreys (PECW).
5.	15%	**Narrow drainage tracts** – sparse narrow (<200 m wide) zones receiving concentrated run-on from units 1 and 2; incised in upper parts.	Shallow duplex on greenstone (7b).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with occasional eucalypt trees (DRAS).

NALLEX LAND SYSTEM (439 km², 0.5% of the survey area)

Gently undulating stony plains supporting acacia tall shrublands and halophytic low shrublands.

Land type: 8

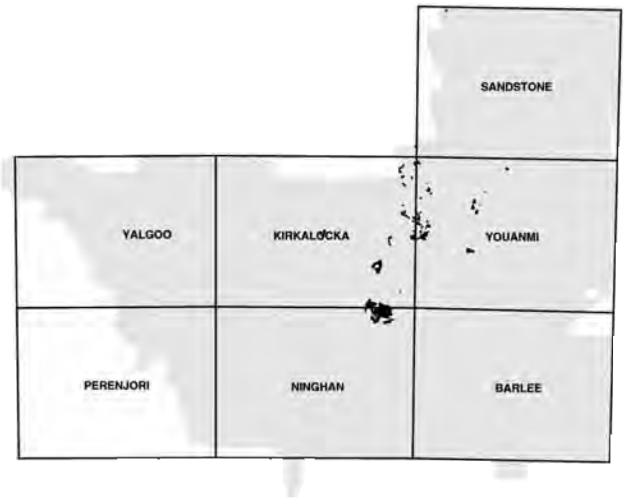
Geology: Coarse-grained Archaean greenstone (often gabbro), Quaternary alluvium and colluvium.

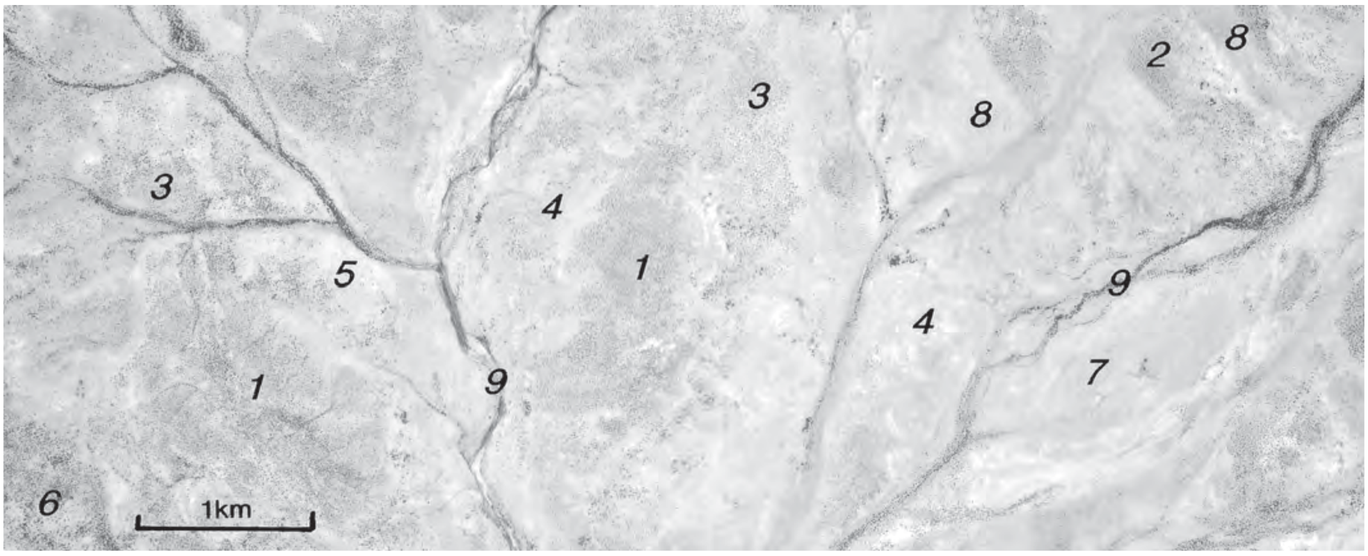
Geomorphology: Erosional and depositional surfaces; gently undulating plains with stony mantles, scattered low hills, ridges and rises, tributary alluvial plains, gilgaied drainage tracts and occasional incised drainage lines.

Land management: Where not protected by a substantial stony mantle, unit 4 is susceptible to water erosion, particularly in areas where shrub cover is reduced and/or the soil surface is disturbed. Lower alluvial plains (unit 7) are mildly susceptible to water erosion. Units 7 and 8 are prone to invasion by short-lived introduced weed plant species. The vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (99 assessments):
Vegetation – good 8%; fair 41%; poor 33%; very poor 18%
Soil erosion – nil 86%; slight 8%; minor 4%; moderate 2%.

Area mapped as sde: 0.6 km² (0.1% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Low hill/rise	3	3
2	Low ridge	–	1
3	Stony plain	20	4
4	Saline stony plain	22	4
5	Calcrete plain	6	–
6	Hardpan plain	14	–
7	Alluvial plain	10	2
8	Gilgaied drainage tract	9	3
9	Drainage tract	10	1
	Other	5	–
	Total	99	18

Nallex land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Low hills and rises** – scattered rounded low hills, rises and footslopes, generally <20 m relief with variable mantles of gabbro and quartz and minor outcrops of gabbro.	Shallow calcareous loams, stony soils and shallow duplex on greenstone (5a, 1, 7b).	Very scattered to scattered (2.5-20% PFC) acacia tall shrublands (GHAS), often dominated by *Acacia quadrimarginea* (granite wattle).
2.	<1%	**Low ridges** – scattered low ridges to 10 m relief with mantles of abundant gabbro and quartz pebbles and cobbles.	Stony soils (1).	Very scattered to scattered (2.5-20% PFC) acacia tall shrublands (GHAS).
3.	25%	**Stony plains** – nearly level to gently undulating plains downslope of units 1 and 2, with variable mantles of quartz, gabbro and ironstone gravels.	Shallow duplex, stony soils and calcareous loams on greenstone (7b, 1, 5a).	Very scattered to scattered (2.5-20% PFC) acacia tall shrublands, prominent tall shrubs including *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) *A. aneura* (mulga) and *A. quadrimarginea*, frequently over a *Ptilotus* obovatus (cotton bush) dominated understorey (SIAS, SAES, SGRS).
4.	25%	**Saline stony plains** – nearly level to very gently undulating erosional plains with variable mantles of gabbro and quartz.	Shallow duplex and clays usually on gabbro (7b, 9a).	Scattered (10-20% PFC) *Maireana pyramidata* (sago bush) low shrublands with acacia tall shrub strata (SBMS).
5.	5%	**Calcrete plains** – slightly raised plains of calcrete to 1 m relief, with mantles of calcrete rubble.	Shallow calcareous loams or red clayey sands on calcrete over gabbro (5a, 2c).	Very scattered to scattered (2.5-20% PFC) *Acacia acuminata* subsp. *burkittii* tall shrublands (JAMS), occasionally with a eucalypt overstorey (CAPW).
6.	5%	**Hardpan plains** – nearly level plains subject to sheet flow, occurring on the margins of the system, sometimes with mantles of fine ironstone or quartz gravel.	Shallow hardpan loams (5d).	Scattered (10-20% PFC) *Acacia aneura* tall shrublands (HPMS, occasionally LHMS).
7.	15%	**Alluvial plains** – nearly level tributary alluvial plains, occasionally with a light mantle of quartz and ironstone pebbles.	Shallow to deep duplexes or clays on hardpan (7c, 8, 9a, 9b).	Very scattered to scattered (2.5-20% PFC) *M. pyramidata* and other halophytic low shrublands (PSAS, PXHS).
8.	10%	**Gilgaied drainage tracts** – tributary drainage tracts with gilgai micro-relief and minor narrow (<10 m wide) shallow (<50 cm deep) channels and nearly circular small drainage foci (<200 m radius).	Deep cracking clays (10).	Scattered (10-20% PFC) *M. pyramidata* low shrublands with perennial grasses in gilgais (GGLS) and moderately close (20-30% PFC) *A. aneura* upperstoreys fringing drainage foci grasslands (ACGU).
9.	10%	**Drainage tracts** – occasional narrow creek lines (<15 m wide) with steep-sided banks (<3 m deep) flanked by levees and terraces to 50 m wide, or narrow (<100 m wide) unincised nearly linear concentrated flow zones.	Deep juvenile soils (7).	Scattered (10-20% PFC) *Atriplex bunburyana* (silver saltbush) or *M. pyramidata* low shrublands (SSAS, PSAS) or moderately close (20-30% PFC) acacia tall shrublands (DRAS).

NALUTHANNA LAND SYSTEM (277 km^2, 0.3% of survey area)

(after Curry *et al.* 1994)

Rough hills and ridges of gabbro above lower stony plains with gilgaied drainage floors supporting mixed acacia shrublands and minor halophytic shrublands and grasslands.

Land type: 1

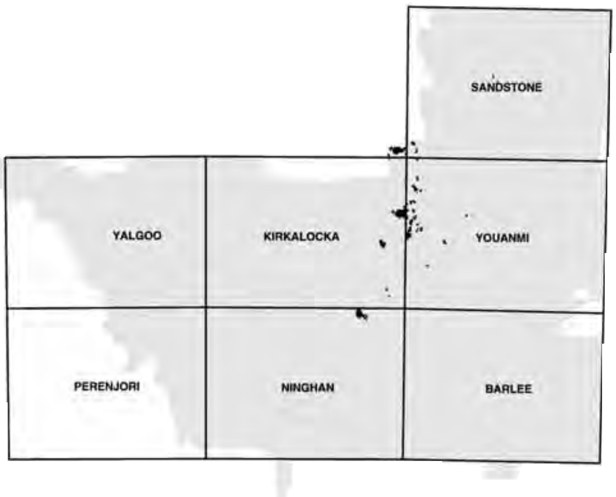
Geology: Archaean gabbro and minor basalt with dolerite intrusives.

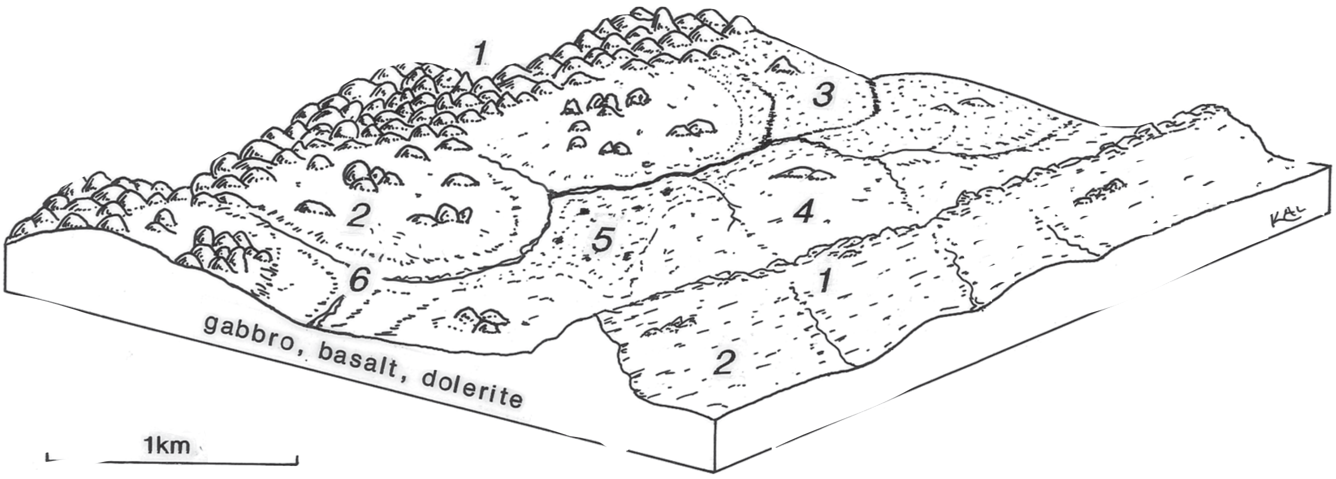
Geomorphology: Erosional surfaces; gabbro strike ridges to 50 m high with unweathered gabbro outcrops above lower, rounded hills of more weathered rocks with dolerite dykes and sills; footslopes and lower stony plains covered with dense gabbro mantles flanking minor valleys of gilgaied alluvium with central meandering drainage channels.

Land management: The lower units (units 3, 5 and 6) support vegetation which is attractive to grazing animals and becomes degraded if grazing control is inadequate. Unit 6 may be moderately susceptible to erosion, other units are generally not susceptible although sloping plains may erode if stony mantles are disturbed.

Traverse condition summary (28 assessments):
Vegetation – good 7%; fair 36%; poor 25%; very poor 32%.
Soil erosion – nil 86%; slight 4%; minor 3%; moderate 7%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hill/strike ridge/low rise	4	5
2	Hillslope	5	2
3	Saline stony plain	2	1
4	Stony plain	4	–
5	Gilgai plain	1	1
6	Narrow drainage floor	9	1
	Other	5	–
	Total	30 *	10

* 2 traverse points not assessed for condition.

Naluthanna land system

Unit area (%)	Landform	Soil	Vegetation
1. 45%	**Hills, strike ridges and low rises** – hills, ridges, tor fields and rocky rises with crests to 50 m (mostly <30 m) and steep upper slopes with mantles of abundant gabbro pebbles, cobbles and stones, also gabbro outcrop.	Stony soils and shallow calcareous loams (1, 5a).	Very scattered to scattered (2.5-20% PFC) tall shrublands of *Acacia acuminata* subsp. *burkittii* (fine-leaf jam) or *A. quadrimarginea* (granite wattle) (GHAS, SIAS).
2. 30%	**Hillslopes** – very gently inclined to gently inclined slopes with variable density mantles of gabbro pebbles and cobbles.	Shallow duplex on gabbro (7b).	Very scattered to moderately close (2.5-20% PFC) tall shrublands of *A. quadrimarginea* and other acacias (GHAS, SIAS, occasional SBMS).
3. 5%	**Saline stony plains** – minor gently undulating plains with mantles of many to abundant pebbles of quartz and gabbro.	Shallow clays or duplex on gabbro (9a, 7b).	Very scattered (2.5-20% PFC) to scattered mixed height shrublands with isolated *Hakea preissii* (needle bush), *Acacia aneura* (mulga), *Maireana pyramidata* (sago bush) and other *Maireana* spp. (SBMS).
4. 10%	**Stony plains** – gently undulating plains with mantles of many to abundant quartz and gabbro pebbles.	Shallow duplex on greenstone (7b).	Very scattered to scattered (2.5-20% PFC) tall shrublands of *A. acuminata* subsp. *burkittii* and *A. quadrimarginea* with non-halophytic undershrubs (GHAS, SAES).
5. 5%	**Gilgai plains** – restricted weakly saline plains flanked by units 2 and 3 with patches of gilgai depressions adjacent to sluggish drainage tracts.	Cracking clays (10).	Very scattered to scattered (2.5-20% PFC) low shrublands of *M. pyramidata* and other halophytes or scattered tussock grasslands dominated by *Eragrostis setifolia* (neverfail grass) (PSAS).
6. 5%	**Narrow drainage floors** – narrow dendritic drainage lines rising in upper parts of system and grading into broader alluvial floors in lower parts usually with shallow, meandering channels <20 m wide.	Shallow red earths on hardpan (5c).	Scattered to moderately close (10-30% PFC) acacia woodlands or tall shrublands (DRAS).

NARRYER LAND SYSTEM (19 km^2, 0.02% of the survey area)

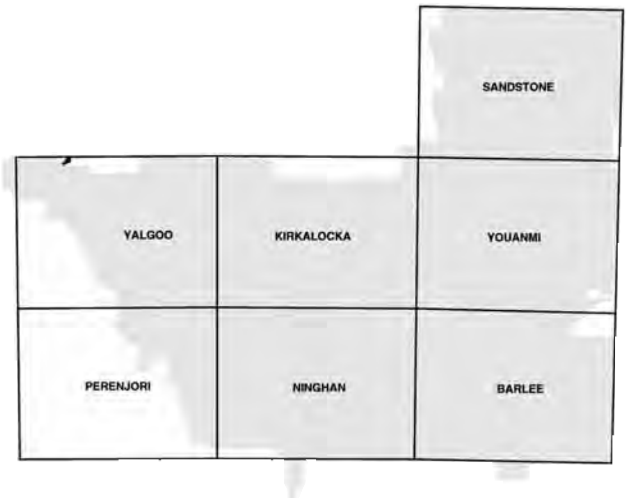
(after Curry *et al.* 1994)

Stony plains and occasional low hills and breakaways on gneiss and granite with sparse acacia shrublands.

Land type: 4

Geology: Archaean banded gneiss, greenstone and quartzite wacke partly overlain by Tertiary laterite and patches of opaline silica; also Quaternary colluvium and alluvium.

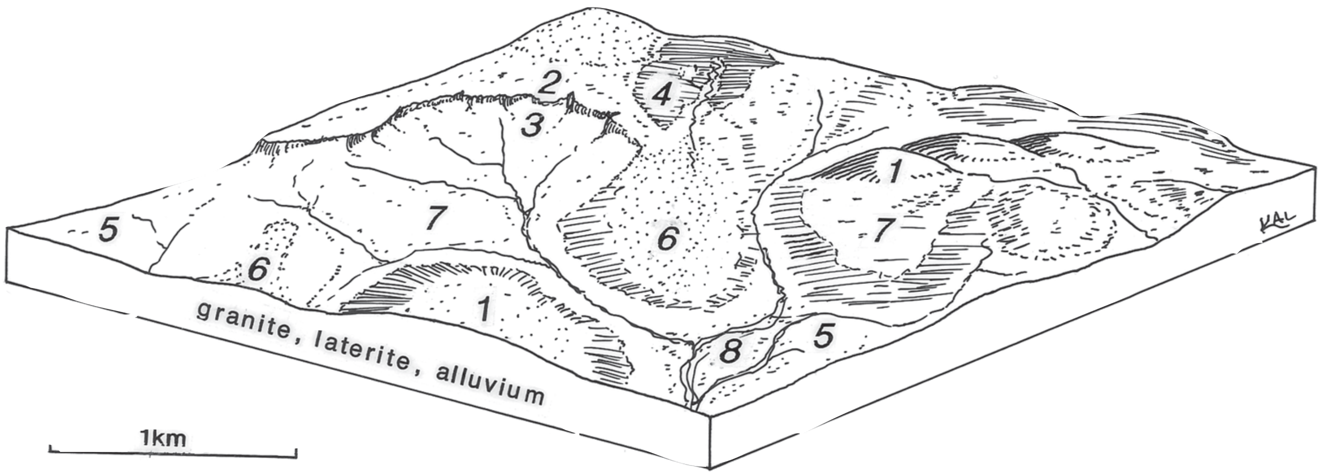
Geomorphology: Erosional surfaces; remnant lateritic plateaux and breakaways to 15 m relief with scree slopes but limited development of pallid zones; rounded hills and occasional ridges to 20 m with mantles of dense ironstone gravel or laterite fragments; broad undulating stony plains and interfluves with patches of exposed laterite capping and minor sandplain; narrow, channelled dendritic drainage tracts with occasional larger channels; overall relief to 20 m, occasionally greater.



Land management: Saline parts of units 3, 6, 7 and 8 support vegetation which is preferred by grazing animals and is thus prone to degradation if control of grazing is inadequate; major units not normally susceptible to erosion due to protective stony mantles but units 3 and 8 are mildly susceptible when vegetation cover is reduced or soil surfaces are disturbed.

Traverse condition summary: Not traversed

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1	Hill, ridge, low stony rise	–	–
2	Breakaway, dissected plateaux	–	–
3	Footslope	–	–
4	Gravelly plain	–	–
5	Sandy bank	–	–
6	Stony plain	–	–
7	Saline stony plain	–	–
8	Drainage tract	–	–
	Other	–	–
	Total	0	0

Narryer land system

Unit area (%)		Landform	Soil	Vegetation
1.	5%	**Hills, ridges, low stony rises** – stony hills and ridges to >20 m and upper slopes with mantles of pebbles, cobbles and stones of ironstone and quartz.	Stony soils and shallow red earths (1, 5c) or coarse red clayey sands on gneiss and granite (2a).	Very scattered to (2.5-20% PFC) scattered mixed height shrublands of *Acacia aneura* (mulga), *A. acuminata* subsp. *burkittii* (fine-leaf jam) and other acacias. (GRHS, SGRS).
2.	3%	**Breakaways and dissected plateaux** – breakaways with scarps to 20 m, very gently inclined stripped surfaces; mantles of abundant quartz and lateritic gravel.	Shallow stony red earths (5b).	Very scattered to scattered (2.5-20% PFC) mixed height variable shrublands dominated by *Acacia, Eremophila* and *Ptilotus* spp. (LACS, BRXS).
3.	5%	**Footslopes** – gently inclined stony footslopes below units 1 and 2, saline in some parts.	Shallow duplex on granite or shallow coarse red clayey sands (7a, 2a).	Scattered (10-20% PFC) mixed shrublands with *Acacia eremaea* (snakewood) and *A. aneura* and halophytic undershrubs.
4.	10%	**Gravelly plains** – gently undulating plains, relief to 15 m on higher parts of unit, mantles of abundant ironstone gravel and pebbles.	Shallow red clayey sands with ferruginous gravel overlying gravel, ironstone or deeply weathered substrates (2b).	Scattered (10-20% PFC) tall or mixed height shrublands dominated by *Acacia ramulosa* (bowgada) or *A.* aff. *coolgardiensis* (sugar brother) with sparse wanderrie grasses (SWGS).
5.	2%	**Sandy banks** – low (<50 cm high) sandy banks and isolated tracts of sand sheet to 1 km long and 0.5 km wide.	Deep red clayey sands (3a).	Scattered to moderately (10-30%-PFC) close tall shrublands of *A. ramulosa, Eremophila forrestii* (Wilcox bush) and wanderrie grasses (WABS).
6.	60%	**Stony plains** – extensive gently undulating stony plains, often saline and with outcrops of granite and gneiss, variable density mantles of pebbles and cobbles.	Shallow red clayey sands (2d).	Shallow duplex over granite,(7a). Stony soils (1). Very scattered to scattered (2.5-20% PFC) *Acacia* and *Eremophila* spp. shrublands with sparse, mostly non-halophytic low shrubs (SAES), occasionally halophytic undershrubs (HMCS).
7.	10%	**Saline stony plains** – level to gently inclined plains, mainly adjacent to deeply weathered parent rocks, with mantles of many to abundant quartz pebbles.	Shallow duplex or clays (7a, 7c, 9a).	Very scattered to scattered (2.5-20% PFC) mixed shrublands dominated by *Acacia* and *Maireana* (bluebush) species (HMCS, SBMS).
8.	5%	**Drainage tracts** – dendritic drainage tracts to 300 m wide with central channels incised to 4 m.	Shallow duplex and red clayey sands over hardpan (7c, 2d).	Moderately close to closed (>20% PFC) woodlands and tall shrublands dominated by *A. ramulosa* (bowgada) and *A. aneura* (CBKW, DRAS).

NERRAMYNE LAND SYSTEM (1,650 km^2, 1.7% of survey area)

(after Curry *et al.* 1994)

Undulating sandy and gravelly plains with low plateaux and breakaways supporting acacia shrublands.

Land type: 7

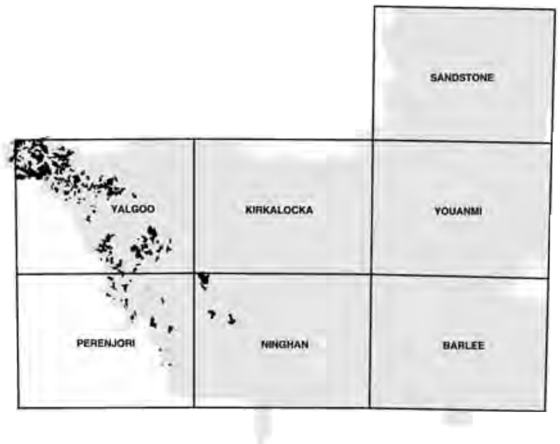
Geology: Archaean granite partly overlain by Tertiary laterite and Quaternary aeolian sandplain and alluvium.

Geomorphology: Mostly erosional surfaces; remnant lateritized plateaux, associated breakaways and footslopes; low, rounded gravel and quartz covered rises and ridges; broad, gently undulating plains with colluvial and alluvial surfaces with mantles of ironstone and quartz gravels, minor sandplain remnants, sparse dendritic drainage patterns; overall relief to 20 m.

Land management: The restricted areas of halophytic vegetation on this system (mostly on units 3 and 8) are subject to preferential grazing by livestock and are thus prone to degradation. The system is not generally susceptible to erosion because of its stoniness.

Traverse condition summary (181 assessments):
Vegetation – good 54%; fair 36%; poor 9%; very poor 1%.
Soil erosion – nil 99%; minor 1%.

Area mapped as sde: Nil



MAP TO BE ADDED ON THE BENCH

No.	Unit name	Traverse recordings	Inventory sites
1	Low rise/hill	1	2
2	Plateau/stripped surface	12	5
3	Footslope	5	1
4	Gravelly plain	17	3
5	Loamy plain/hardpan plain	46	2
6	Sand sheet/gravelly sand sheet	27	4
7	Stony plain/gritty surfaced plain	61	5
8	Narrow drainage zone	10	1
	Other	2	–
	Total	181	23

Nerramyne land system

Unit	area (%)	Landform	Soil	Vegetation
1.	3%	**Low rises and hills** – undulating low rises and small hills of granite or weathered granite. Mantles of variable density granite or lateritic gravel, also granite outcrop, relief to 20 m.	Shallow coarse red clayey sands on granite or gravel (2a).	Scattered to moderately close (10-30% PFC) mixed height acacia shrublands often with *Borya sphaerocephala* in understorey (GABS, LACS).
2.	5%	**Plateaux and stripped surfaces** – gently inclined surfaces above low breakaways with pebble mantles of lateritic gravel and weathered granite, relief mostly to 10 m, occasionally to 20 m.	Stony soils (1).	Very scattered to scattered (2.5-20% PFC) mixed height acacia shrublands typically with *Thrypromene, Eriostemon* and *Eremophila* spp. mid and low shrubs (BRXS).
3.	2%	**Footslopes below breakaways** – gently inclined often quartz-strewn slopes, some lying below minor pallid zone development, usually <300 m long.	Shallow coarse red clayey sands or duplex over decomposing granite (2a, 7a).	Very scattered to scattered (2.5-20% PFC) halophytic low shrublands (BCLS).
4.	10%	**Gravelly plains** – gently undulating plains on weathered granite usually with mantles of abundant ironstone gravel and pebbles.	Shallow red earths and shallow red clayey sands with ferruginous gravel (5c, 2b).	Scattered to moderately close (10-30% PFC) mixed height shrublands mostly *Acacia ramulosa* (bowgada) and *A. quadrimarginea* (granite wattle) with *Eremophila* spp. low shrubs and occasional wanderrie grasses (LACS, LHMS).
5.	20%	**Loamy plains/hardpan plains** – gently undulating plains without surface mantle.	Shallow red earths, occasionally deep duplex soils (4c, 8).	Moderately close to close (20-50% PFC) tall shrublands of *Acacia aneura* (mulga), *A. ramulosa* and *A.* aff. *coolgardiensis* (sugar brother) and occasional wanderrie grasses (HCAS, PLMS).
6.	10%	**Sand sheets/gravelly sand sheets** – isolated areas of remnant sandplain, usually <1 km in extent and sloping <1%, occasionally steeper.	Deep red clayey sands or shallow red earths on gravel (3a, 5c).	Moderately close to close (20-50% PFC) tall shrublands of *A. ramulosa, A.* aff. *coolgardiensis* and occasional wanderrie grasses (SACS, SWGS).
7.	35%	**Stony plains and gritty surfaced plain**s - gently undulating plains on granite, downslope of units 1, 2, 3 and 5, with mantles of many to abundant quartz and ironstone pebbles and frequent granite outcrop.	Shallow coarse red clayey sands on granite (2a).	Scattered to moderately close (10-30% PFC) tall shrubland of *A. quadrimarginea* and other acacias, commonly with *Eremophila platycalyx* (granite poverty bush), *Ptilotus obovatus* (cotton bush) and *Borya sphaerocephala* (SAES, SGRS, GABS).
8.	15%	**Narrow drainage zones** – narrow tracts (<500 m wide) from catchments in the higher units; creeklines locally flooding into broader, saline alluvial floors, otherwise continuing as zones with channels, locally incised over hardpan.	Variable depth duplex over hardpan or parent material (7c, 7a, 8).	Very scattered (2.5-10% PFC) halophtyic low shrublands including *Halosarcia* (samphire) and *Frankenia* (frankenia) spp. (SAMP, FRAN) or moderately close (20-30% PFC) tall and mixed height acacia shrublands (CBKW, DRAS).

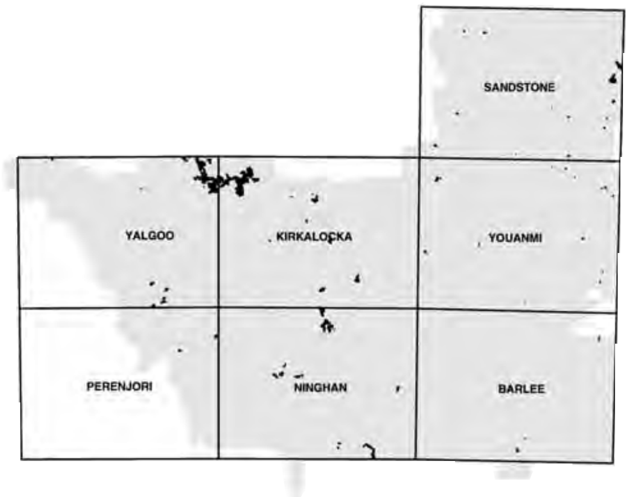
NORIE LAND SYSTEM (755 km², 0.8% of the survey area)

(after Mabbutt *et al.* 1963)

Granite hills with exfoliating domes and extensive tor fields supporting acacia shrublands.

Land type: 1

Geology: Archaean biotitic and porphyritic granite and banded gneiss, minor Tertiary laterite and Quaternary alluvium and colluvium.

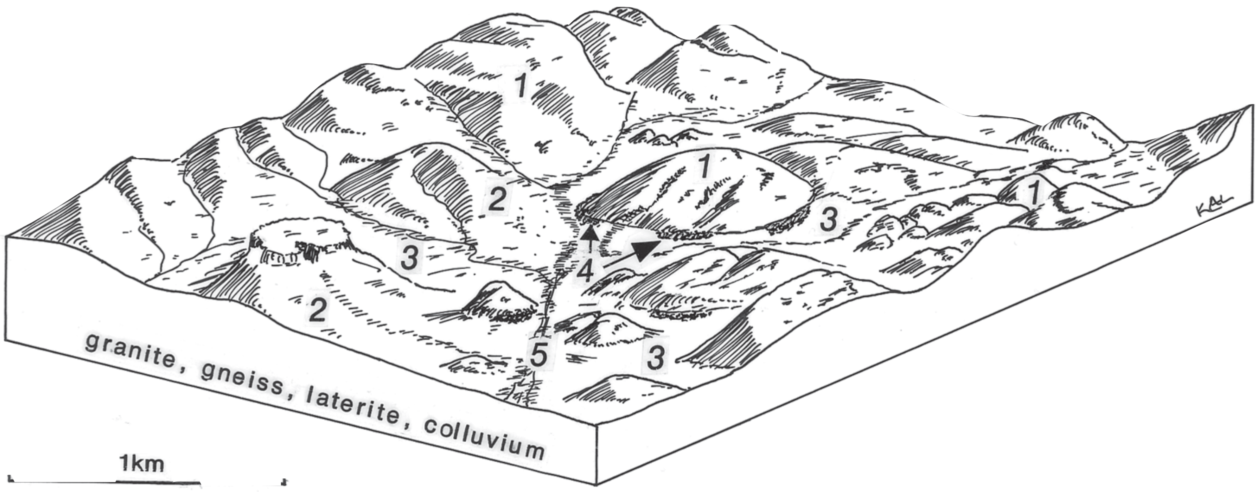


Geomorphology: Erosional surfaces; mainly low hills of unweathered granite with bare slopes and extensive rock outcrop; clusters of exfoliating granite tors with large batholiths to 50 m high and occasional low breakaways; sandy surfaced footslopes and plains below hills and tor fields, with narrow alluvial fans tributary to minor drainage tracts; overall relief usually 20 to 100 m.

Land management: Footslopes and drainage tracts (units 2 and 5) are slightly susceptible to accelerated erosion. Drainage foci at bases of large granite domes and hills support dense acacia shrubland associations in which kite leaf poison (*Gastrolobium laytonii*) is locally common. Presence of poison, especially in areas where it grows away from the confines of thickets in the drainage foci, may restrict use for livestock.

Traverse condition summary (33 assessments):
Vegetation – good 61%; fair 36%; poor 3.
Soil erosion – nil 97%; slight 3%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1	Hill/dome/tor field	5	3
2	Footslope	3	1
3	Gritty surfaced plain/stony plain	17	–
4	Drainage focus	–	2
5	Drainage tract	5	–
	Other	4	–
	Total	36 *	6

* 3 traverse points not assessed for condition.

Norie land system

Unit	area (%)	Landform	Soil	Vegetation
1.	50%	**Hills, domes and tor fields** – hills, domes and tor fields of granite to 50 m high, much rock outcrop with exfoliating surfaces and few to abundant granite cobbles and stones. Occasional low breakaways.	Shallow coarse red clayey sands (2a) restricted to pockets on domes and tors; stony soils on hills (1).	Mostly bare on domes; very scattered to scattered (2.5-20% PFC) mixed shrublands with *Acacia aneura* (mulga), *A. quadrimarginea* (granite wattle), *Eremophila exilifolia* (little tupentine poverty bush) and *E. platycalyx* (granite poverty bush) as common shrubs (GRHS) on hills and tors.
2.	20%	**Footslopes** – gently inclined footslopes below unit 1.	Shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) mixed shrublands with *A. quadrimarginea* and *E. exilifoli*a as common shrubs (GRHS), occasionally halophytic low shrubs.
3.	20%	**Gritty surfaced plains and stony plains** - level to gently undulating plains, with mantles of variable density quartz grit and granitic pebbles and stones.	Shallow red earths on granite (5c).	Very scattered to scattered (2.5-20% PFC) acacia-eremophila shrublands (SGRS, SAES).
4.	<1%	**Drainage foci** – restricted areas fringing granite domes and hills, receiving concentrated run-on.	Variable depth red clayey sands and red earths over granite (2d, 3a, 5c, 6a).	Closed (>50% PFC) acacia tall shrublands or woodlands, including *A. aneura* (mulga) and *A. tetragonophylla* (curara) (GRMU) and close (30-50% PFC) mixed thickets including *Calycopeplus ephedroides* and *Kunzea pulchella* (UFTH).
5.	10%	**Drainage tracts** – narrow valley floors and drainage tracts, often with central shallow incised channels, mostly <20 m wide.	Variable depth red clayey sands or red earths on granite (2d, 3a, 5c, 6a).	Scattered (10-20% PFC) acacia tall shrublands, dominated by *A. aneura* or *A. quadrimarginea* (DRAS), occasionally halophytic low shrubs.

NUBEV LAND SYSTEM (133 km², 0.1% of the survey area)

(after Pringle *et al.* 1994)

Stony plains, minor limonitic low rises and drainage floors supporting mulga and halophytic shrublands.

Land type: 7

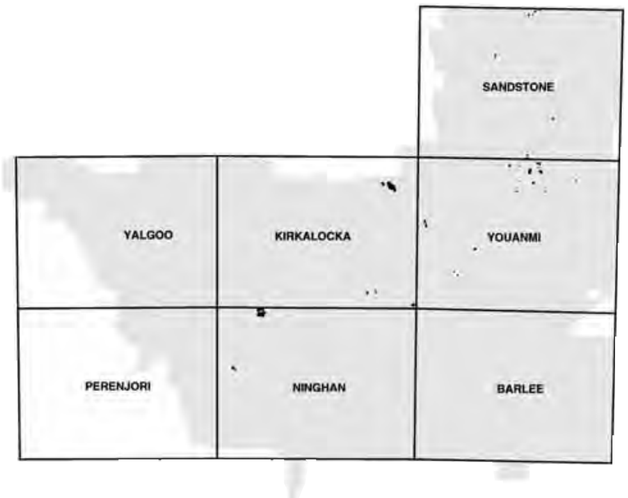
Geology: Minor Archaean greenstone, Tertiary ferruginous duricrust, Quaternary colluvium and alluvium.

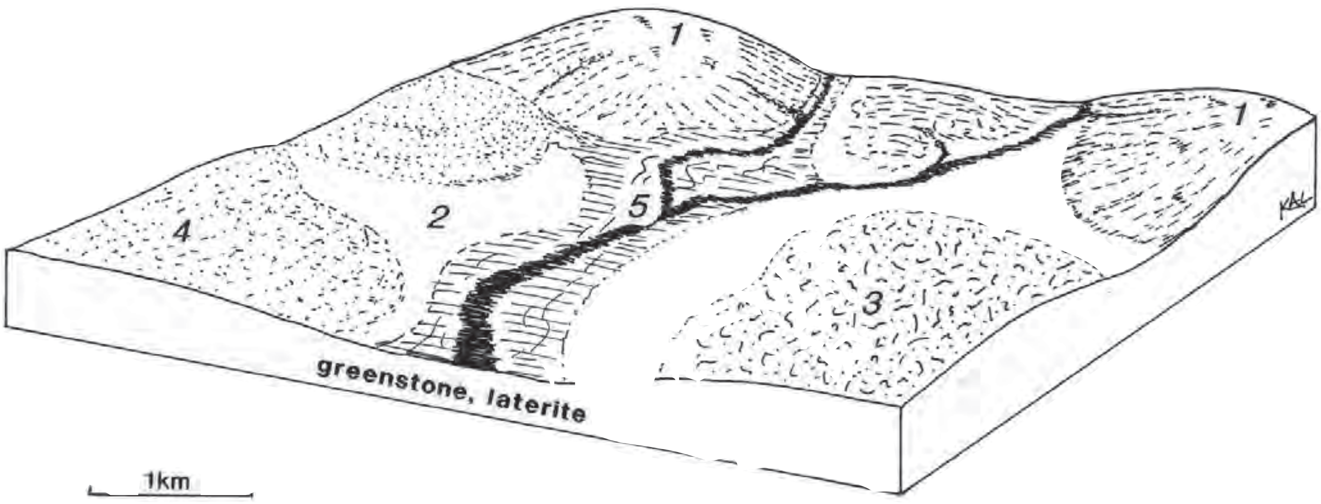
Geomorphology: Mainly erosional surfaces; gently undulating plains and low rises frequently with ferruginous duricrust and colluvium, and drainage floors receiving concentrated flow from adjacent uplands. Relief to 15 m.

Land management: Drainage zones (unit 5) are moderately susceptible to soil erosion, particularly where perennial shrub cover is substantially reduced or the soil surface is disturbed. Disturbance of the protective stone mantle on saline stony plains (unit 2) is also likely to initiate water erosion. Much of the vegetation of this land system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (30 assessments):
Vegetation – good 20%; fair 34%; poor 33%; very poor 13%.
Soil erosion – nil 94%; slight 3%; minor 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Low rise	3	2
2	Saline stony plain	11	–
3	Stony plain	7	–
4	Gravelly plain	9	–
5	Drainage zone	2	–
	Other	3	–
	Total	35 *	2

* 5 traverse points not assessed for condition.

Nubev land system

Unit area (%)		Landform	Soil	Vegetation
1.	16%	**Low rises** – rises (<10 m relief) with ferruginous duricrusts and abundant mantles of ironstone pebbles and cobbles.	Shallow red clayey sands with ferruginous gravel or shallow red earths, on greenstone (2b, 5c).	Very scattered to scattered (2.5-20% PFC) *Acacia aneura* (mulga) tall shrublands, (SIMS, LHMS) or mixed low shrublands locally with weakly halophytic species (USBS).
2.	25%	**Saline stony plains** – level to very gently inclined plains with mantles of many quartz and ironstone pebbles.	Shallow red earths or duplex, on greenstone (5c, 7b).	Scattered (10-20% PFC) low halophytic shrublands, frequently dominated by *Maireana pyramidata* (sago bush) (SBMS).
3.	27%	**Stony plains** – gently undulating plains with mantles of abundant ironstone and quartz pebbles.	Shallow red earths on greenstone or red clayey sands on hardpan (5c, 2d).	Very scattered to scattered (2.5-10% PFC) *A. aneura* tall shrublands commonly with mixed understoreys including low *Maireana* spp. (USBS, SIMS, SAES).
4.	20%	**Gravelly plains** – very gently inclined to level plains receiving diffuse run-on, with mantles of abundant fine ironstone gravel.	Shallow red earths on greenstone (5c).	Very scattered (2.5-10% PFC) *A. aneura* tall shrublands (LHMS).
5.	12%	**Drainage zones** – usually unchannelled drainage floors, 100 to 700 m wide, with quartz and ironstone pebble mantles.	Shallow saline duplex on hardpan (7c).	Scattered (10-20% PFC) halophytic low shrublands with occasional *A. aneura* tall shrubs (PSAS, minor SSAS, also DRAS).

OLYMPIC LAND SYSTEM (1,135 km^2, 1.2% of the survey area)

Irregular plains with occasional low breakaways and tor fields on granite supporting acacia shrublands.

Land type: 4

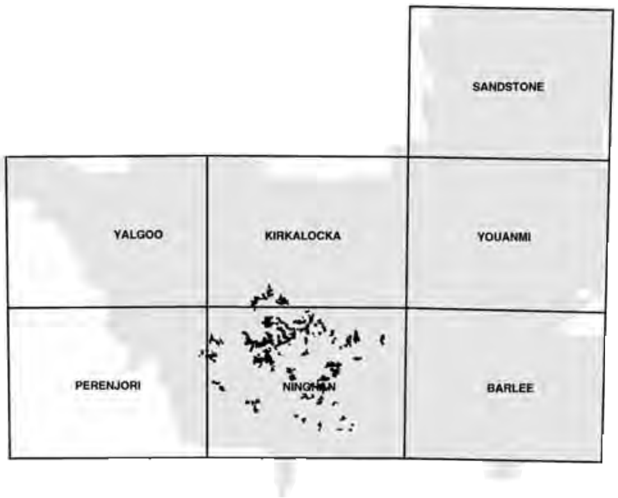
Geology: Archaean granite, Tertiary laterite and Quaternary sand.

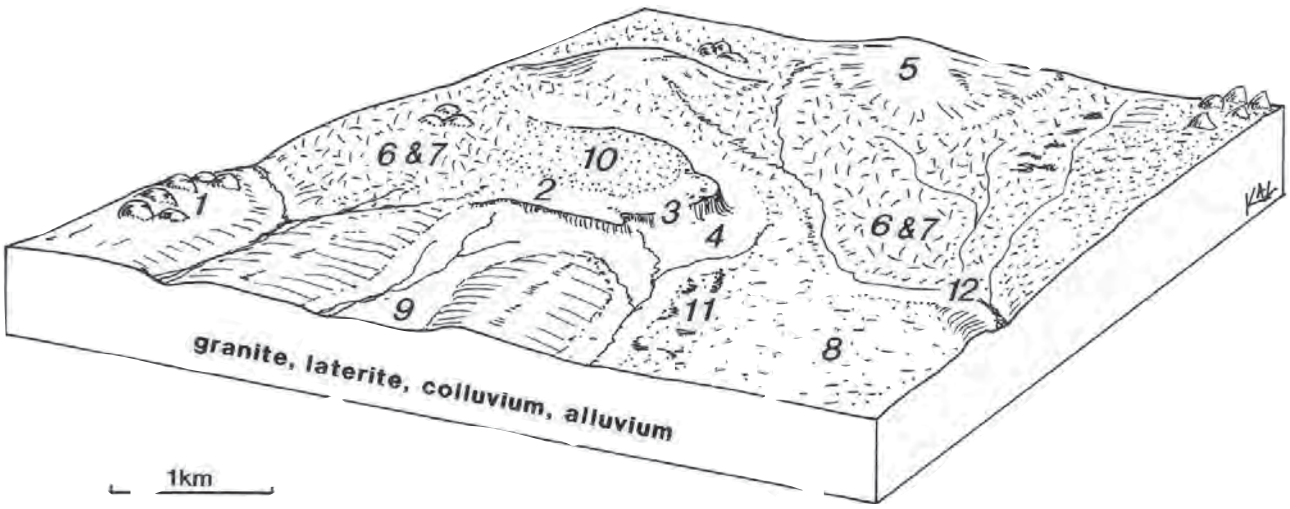
Geomorphology: Erosional surfaces; level to gently undulating plains with gritty surfaces or with stone mantles, sandy tracts with gravelly surfaces; minor domes, tor fields, low rises (relief up to 15 m) and low breakaways with very gently inclined footslopes, minor alluvial plains and narrow drainage tracts receiving run-on, infrequent drainage foci.

Land management: This system supports fairly dense vegetation which is only moderately attractive to grazing animals. It is not generally prone to overgrazing, loss of cover or accelerated erosion. The drainage foci (unit 11) and some other units occasionally support kite leaf poison (Gastrolobium laytonii) which restricts pastoral use.

Traverse condition summary (127 assessments):
Vegetation – good 61%; fair 35%. poor 4%.
Soil erosion – nil 99%; slight 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Dome/tor field	1	–
2	Stripped surface	5	–
3	Breakaway	1	1
4	Lower footslope	6	1
5	Low rise	–	3
6	Gritty-surfaced plain	45	7
7	Stony plain	6	2
8	Loamy plain	47	–
9	Alluvial plain	2	1
10	Sand sheet	14	2
11	Drainage foci	–	3
12	Drainage tract	1	–
	Total	131 *	20

* 4 traverse points not assessed for condition.

Olympic land system

Unit	area (%)	Landform	Soil	Vegetation
1.	3%	**Domes and tor fields** – domes and tors on granite to 15 m, much rock outcrop with exfoliating surfaces.	Pockets of shallow coarse red clayey sands (2a).	Mostly bare, isolated (<2.5% PFC) pockets of vegetation including *Kunzea pulchella* (granite kunzea) and *Borya sphaerocephala.*
2.	5%	**Stripped surfaces** – level plains usually adjacent to low breakaways, with exposures of lateritic gravels or duricrust.	Shallow red clayey sands with ferruginous gravel on laterite (2b).	Very scattered (2.5-10% PFC) mixed shrublands, *Thryptomene mucronata* and *T. decussata* are common species (BRXS).
3.	2%	**Breakaways** – low breakaways (to 5 m relief) on granite, with scarp faces and short stony scree slopes.	Pockets of shallow coarse red clayey sands (2a).	Very scattered (2.5-10% PFC) mixed shrublands including *Thryptomene* spp. and *Eremophila latrobei* (warty-leaf eremophila) (BRXS).
4.	5%	**Lower footslopes** – very gently inclined short (<300 m) footslopes below units 1, 2 and 3.	Shallow duplex on granite (7a).	Scattered (10-20% PFC) halophytic low shrublands, sometimes with patchy eucalypts (BCLS).
5.	5%	Low rises – low rises (to 10 m) on granite, with granite outcrop.	Shallow coarse red clayey sands or red earths on granite (2a, 5c).	Scattered (10-20% PFC) *Acacia quadrimarginea* (granite wattle) – *Eremophila forrestii* (Wilcox bush) shrublands (SGRS).
6.	30%	Gritty surfaced plains – level to gently undulating plains with granite outcrop and gritty surfaces of fine quartz pebbles and coarse sand.	Shallow coarse red clayey sands on granite (2a).	Scattered to moderately close (10-30% PFC) *T. mucronata* mid height shrubland or scattered *Eremophila forrestii* – *Ptilotus obovatus* (cotton bush) mid to low shrubland, with *A. quadrimarginea* tall shrubs (SGRS, GABS).
7.	5%	Stony plains – gently undulating plains with mantles of variable density granite pebbles and cobbles.	Shallow red earths and coarse red clayey sands on granite (5c, 2a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands including *Acacia acuminata* (jam), *A. acuminata* subsp. *burkittii* (fine-leaf jam) and *A. quadrimarginea* (SAES, GABS).
8.	30%	Loamy plains – level to gently undulating plains with loamy soils receiving diffuse sheet flow.	Deep red earths and sandy red earths (6a, 4).	Moderately close (20-30% PFC) acacia tall shrublands with *Acacia aneura* (mulga), *A. ramulosa* (bowgada), *A. acuminata* subsp. *burkittii* and scattered wanderrie grasses (PLMS, MUBW).
9.	3%	Alluvial plains – very gently inclined plains receiving sheet flow.	Shallow duplex on granite (7a).	Moderately close (20-30% PFC) *Acacia masliniana* (spiny snakewood) tall shrublands with halophytic undershrubs (ASWS).
10.	10%	Sand sheets – gently undulating sandy tracts with few quartz and granite pebbles.	Deep red clayey sands on granite (3a).	Moderately close (20-30% PFC) acacia tall shrublands mostly *A. ramulosa* (SACS, SWGS), occasionally with myrtaceous low and mid shrubs (SCMS).
11.	<1%	Drainage foci – depressions to 60 m wide, fringing granite domes and stripped surfaces, receiving concentrated run-on from these upland areas.	Variable soils – shallow coarse red clayey sands, hardpan loams and deep duplexes (2a, 5d, 8).	Closed (>50% PFC) mixed tall shrublands, shrubs include *Gastrolobium laytonii* (kite leaf poison), *Acacia tetragonophylla* (curara), *A. acuminata* subsp. *burkittii* and *Dodonaea* spp. (UFTH).
12.	2%	Drainage tracts – narrow (<250 m) tracts with minor channels.	Shallow coarse red clayey sands and hardpan loams (2a, 5d).	Moderately close (20-30% PFC) acacia woodlands or tall shrublands (CBKW).

PINDAR LAND SYSTEM (1,519 km², 1.6% of the survey area)

Loamy plains surrounded by sandplain supporting York gum woodlands and acacia shrublands.

Land type: 19

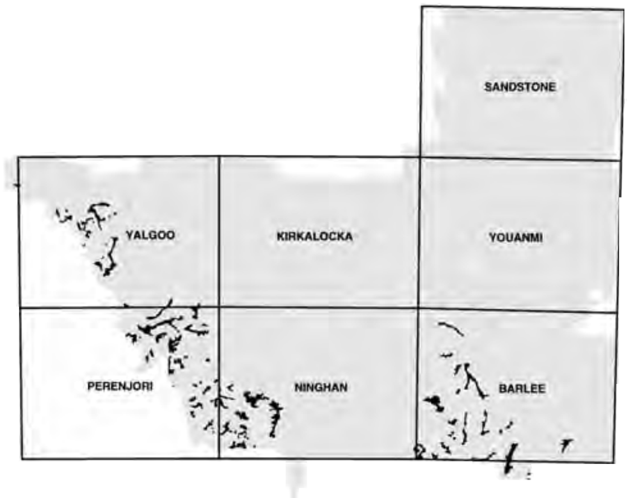
Geology: Quaternary sand and Cainozoic alluvial and colluvial deposits.

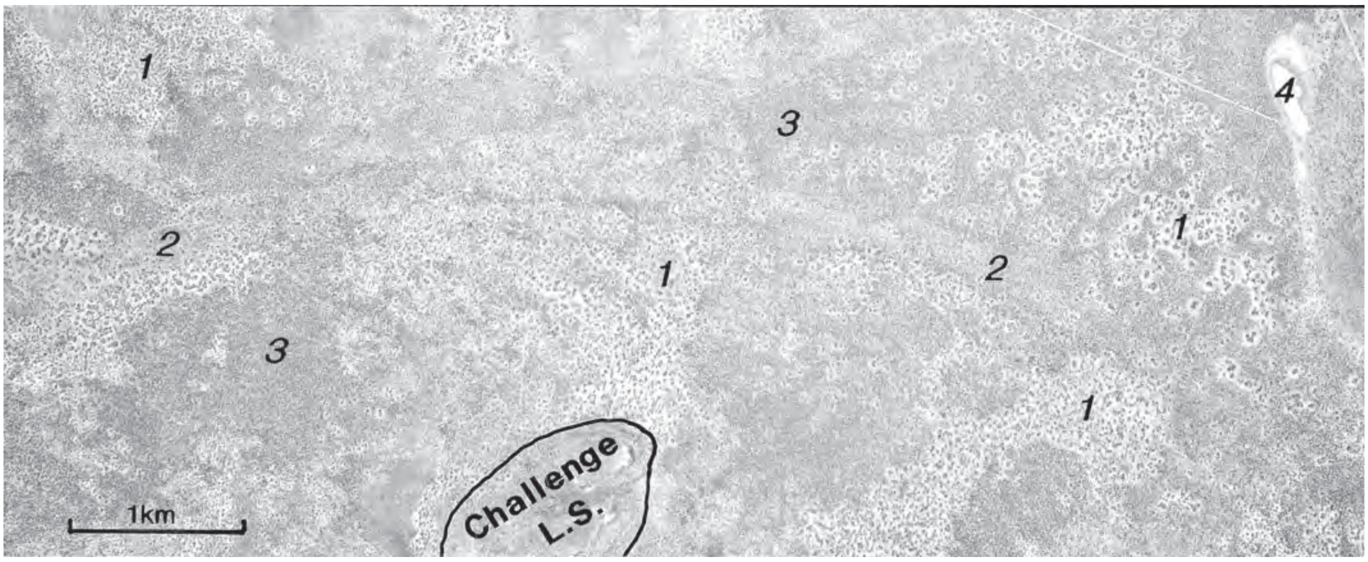
Geomorphology: Depositional surfaces; level plains receiving diffuse run-on, level sand sheets and nearly level plains receiving more concentrated flow.

Land management: This system generally has a low susceptibility to erosion because of the lack of slope, the coarse surface soil texture of the major unit (unit 1) and the stability provided by tall shrubs and eucalypt trees. The halophytic low shrubs of unit 2 are subject to preferential grazing and may be removed if total grazing pressure is too high.

Traverse condition summary (126 assessments):
Vegetation – good 45%; fair 41%; poor 13%; very poor 1%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Loamy plain	100	10
2	Alluvial plain	7	1
3	Sand sheet	15	5
4	Drainage focus	–	2
	Other	6	–
	Total	128	18

* 2 traverse points not assessed for condition.

Pindar land system

Unit area (%)		Landform	Soil	Vegetation
1.	80%	**Loamy plains** – level plains receiving very diffuse run-on.	Deep and shallow red earths on hardpan, occasionally shallow red clayey sands on hardpan (6a, 5c, 2d).	Scattered to moderately close (10-30% PFC) eucalypt woodland or acacia tall shrubland with eucalypt overstorey. Eucalypts are most commonly *Eucalyptus loxophleba* (York gum), occasionally *E. celastroides* or *E. transcontinentalis*. Acacias include *Acacia ramulosa* (bowgada) and *A. acuminata* subsp. *burkittii* (fine-leaf jam). Common undershrubs include *Ptilotus obovatus* (cotton bush) *Olearia* spp. and *Senna artemisioides* subsp. *petiolaris* (desert cassia). Perennial grasses include *Monachather paradoxa* (broad-leaved wanderrie) and *Stipa* spp. (PYAW).
2.	5%	**Alluvial plains** – nearly level plains receiving more concentrated flow.	Shallow duplex on hardpan (7c).	Moderately close (20-30% PFC) *Eucalyptus loxophleba* woodland with *Atriplex* spp. (saltbush) understorey (PYCW).
3.	15%	**Sand sheets** – level sandy tracts.	Deep red clayey sands (3a).	Moderately close to close (20-50% PFC) acacia mid to tall shrubland (SACS), occasionally with *E. loxophleba* or *Callitris glaucophylla* (native pine) overstorey (MAAS, PINW) rarely with spinifex understorey.
4.	<1%	**Drainage foci** – small (usually <200 m in extent) depositional areas receiving run-on.	Deep clays (9b).	Scattered (10-20% PFC) *Melaleuca uncinata* tall shrubland with an *Eriachne flaccida* (claypan grass) layer (MESS).

RACECOURSE LAND SYSTEM (53 km^2, 0.1% of survey area)

Partly calcreted alluvial plains with dense acacia shrublands and bluebush and saltbush low shrublands (only found near Yalgoo in the west of the survey area).

Land type: 17

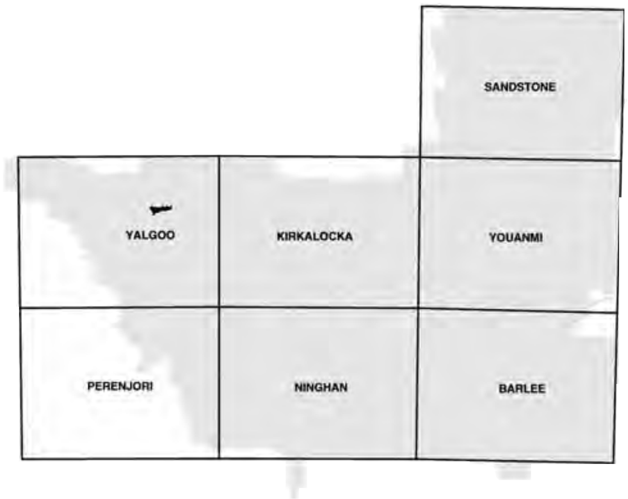
Geology: Quaternary alluvium, hardpan and calcrete.

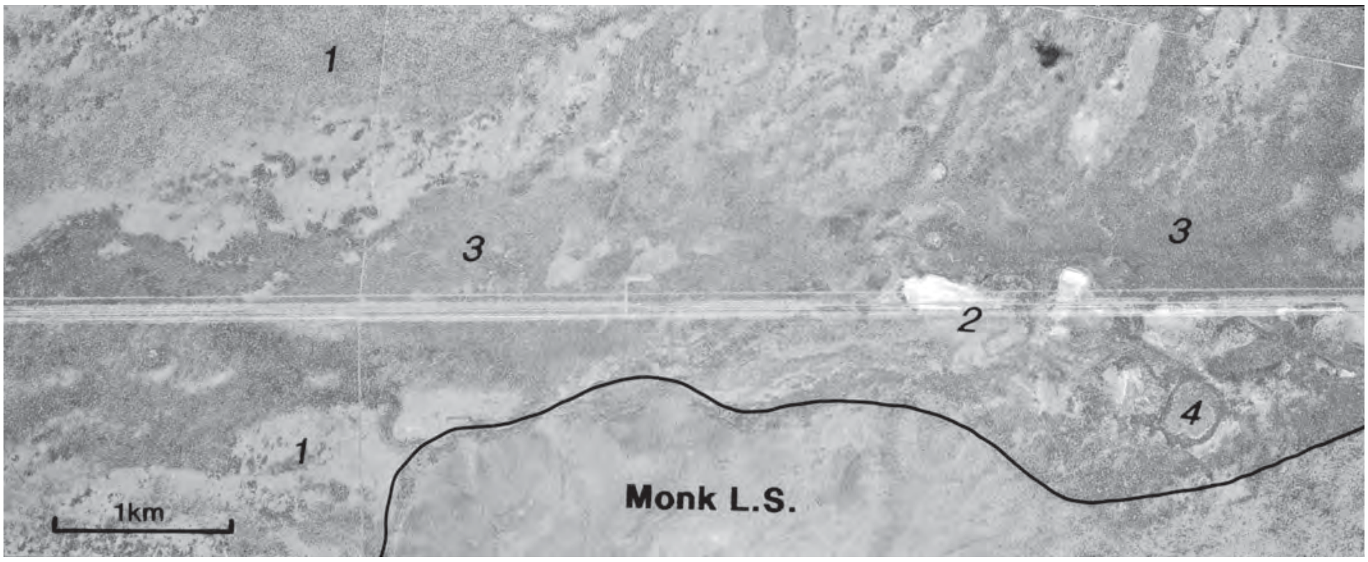
Geomorphology: Depositional surfaces, partly calcreted valley fill; broad alluvial plains and unchannelled drainage tracts receiving sheet flow, minor calcrete platforms, occasional drainage foci and claypans; overall relief <5 m.

Land management: Alluvial plains (unit 1) are moderately susceptible to water erosion if cover of perennial low shrubs is substantially reduced. The vegetation contains many species which are attractive to a wide range of grazing animals and land managers should aim to control total grazing pressure.

Traverse condition summary (10 assessments):
Vegetation – good 60%; fair 20%; poor 10%; very poor 10%
Soil erosion – nil 90%; severe 10%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Alluvial plain	5	3
2	Calcrete platform	1	–
3	Wide drainage tract	4	–
4	Drainage focus	–	1
	Total	10	4

Racecourse land system

Unit area (%)	Landform	Soil	Vegetation
1. 45%	**Alluvial plains** – nearly level plains to 4 km in extent, subject to diffuse sheet flow.	Deep duplex, and deep clays (8, 9b) or shallow duplexes on hardpan (5c).	Very scattered to moderately close (2.5-30% PFC) low shrublands of *Maireana* spp. (bluebush), *Atriplex bunburyana* (silver saltbush) and *Cratystylis subspinescens* (sage) with patchy *Acacia* spp. tall shrubs (PXHS, ASWS, SSAS).
2. 5%	**Calcrete platforms** – small platforms to 300 m in extent and elevated to 1 m above other units, mantles of variable density calcrete rubble.	Shallow calcareous loams (5a).	Moderately close (20-30% PFC) tall shrublands of *Acacia acuminata* subsp. *burkittii* (fine-leaf jam), *A. sclerosperma* (limestone wattle), *A. tysonii,* and other calciphytes (JAMS, CCAS).
3. 48%	**Wide drainage tracts** – broad, very gently inclined drainage zones to 2 km wide, subject to sheet through-flow.	Deep clayey or duplex soils (9b, 8), shallow calcareous loams and red earths on calcrete and hardpan (5a).	Moderately close (20-30% PFC) *Acacia tetragonophylla* (curara) tall shrublands with sparse *Eriachne flaccida* (claypan grass); numerous other *Acacia* spp. on calcareous sites (mostly DRAS).
4. 2%	**Drainage foci** – swamps and claypans usually 50 to 200 m in diameter, (occasionally larger), subject to episodic inundation.	Shallow red earths (5c).	Swamps with moderately close to closed (>20% PFC) *A. tetragonophylla* or *Melaleuca* spp. tall shrublands (DRAS, MESS). Claypans unvegetated.

RAINBOW LAND SYSTEM (666 km^2, 0.7% of the survey area)

(after Pringle *et al.* 1994)

Hardpan plains supporting mulga shrublands.

Land type: 13

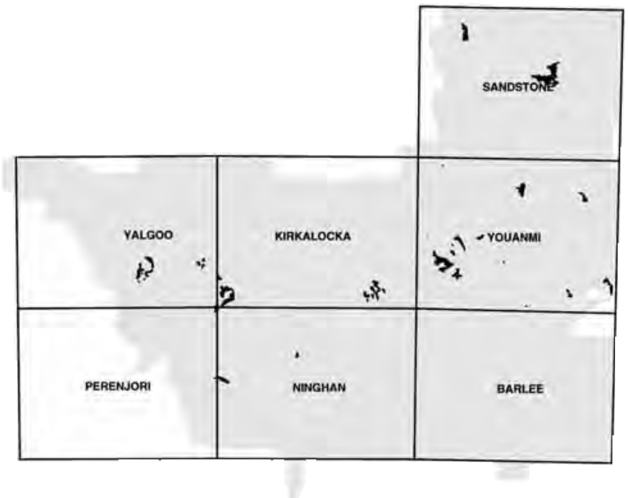
Geology: Cemented Quaternary alluvium.

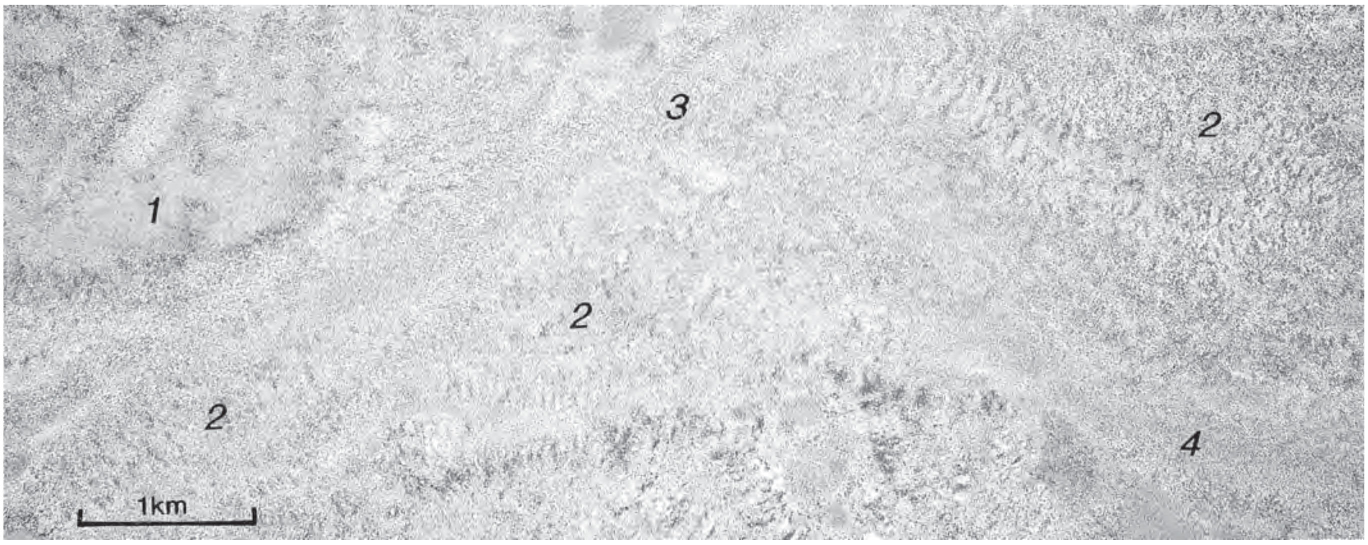
Geomorphology: Depositional surfaces; alluvial plains subject to sheet flow, frequently with mantles of fine ironstone gravel and sparse, generally narrow and unincised concentrated drainage tracts.

Land management: This system is generally not susceptible to soil erosion. However, impedance of sheet flow can initiate erosion and cause water starvation and consequent loss of vigour in vegetation downslope.

Traverse condition summary (105 assessments):
Vegetation – good 24%; fair 45%; poor 26%; very poor 5%.
Soil erosion – nil 97%; minor 2%; severe 1%.

Area mapped as sde: 0.9 km^2 (0.1% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Stony hardpan plain	10	1
2	Hardpan plain/gravelly hardpan plain	84	3
3	Loamy plain	8	–
4	Drainage tract	3	–
	Other	2	–
	Total	107 *	4

* 2 traverse points not assessed for condition.

Rainbow land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Stony hardpan plains** – short (<500 m long) very gently inclined plains with mantles of ironstone and quartz pebbles.	Shallow hardpan loams or red earths on hardpan (5d, 5c).	Scattered (10-20% PFC) acacia tall shrublands (LHMS, HPMS). Acacia species include *Acacia aneura* (mulga) *A. grasbyi* (miniritchie) and *A. tetragonophylla* (curara).
2.	75%	**Hardpan plains/gravelly hardpan plains** – level to very gently inclined plains subject to sheet flow, often with mantles of fine ironstone gravel.	Shallow and deep red earths on hardpan (5c, 6a) or deep red clayey sands on gravel (3a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (HPMS, HCAS). Acacias include *A. ramulosa* (bowgada) and *A. aneura.*
3.	10%	**Loamy plains** – level to very gently inclined tracts receiving diffuse run-on from units 1 and 2.	Deep red earths (6a).	Scattered to moderately close (10-30% PFC) *A. aneura* tall shrublands with occasional wanderrie grasses (PLMS).
4.	5%	**Drainage tracts** – sparse unchannelled drainage zones (to 600 m wide) receiving concentrated run-on.	Deep red earths (6a).	Moderately close to close (20-50% PFC) *A. aneura* tall shrublands (DRAS, HPMS).

RANCH LAND SYSTEM (298 km², 0.3% of the survey area)

(after Pringle *et al.* 1994)

Hardpan plains and prominent broad drainage tracts supporting dense mulga shrublands.

Land type: 13

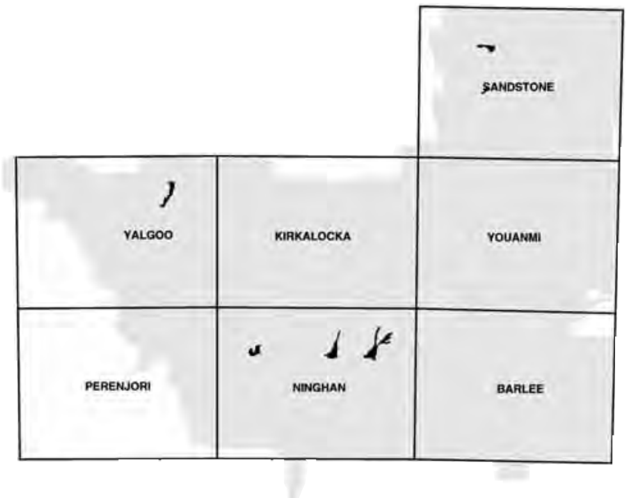
Geology: Quaternary cemented alluvium and sand derived mainly from granitic rocks.

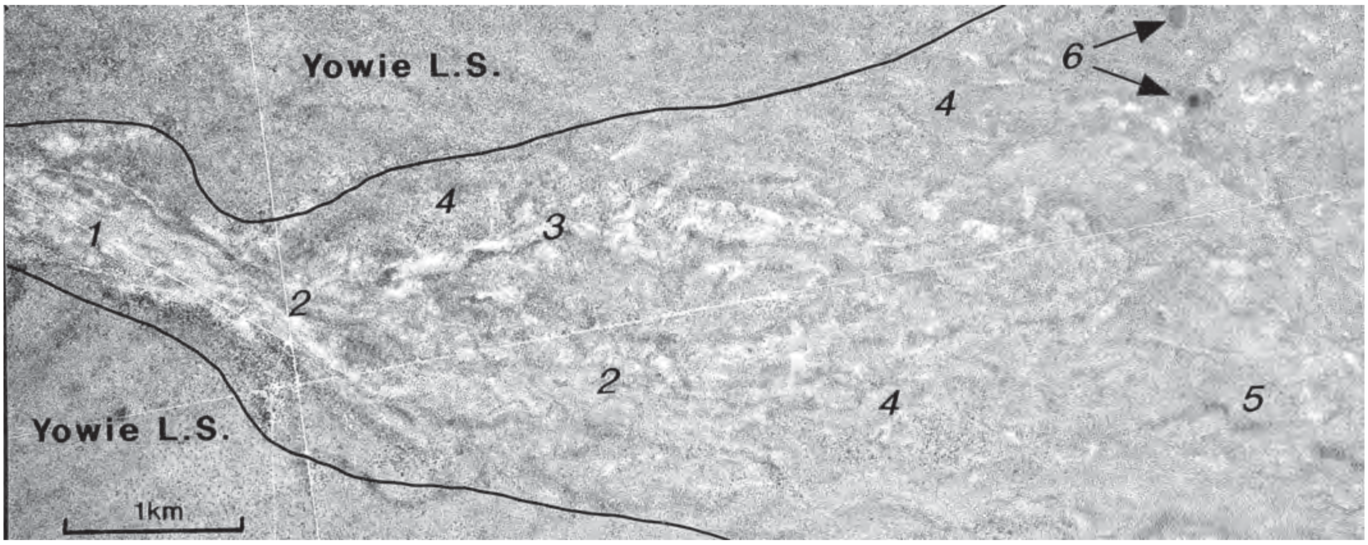
Geomorphology: Depositional surfaces; extensive level to very gently inclined plains subject to variable intensity sheet flow with occasional incised creeks in upper tracts dispersing into concentrated flow zones with scattered drainage foci. Minor sandy tracts and claypans in lower areas adjacent to salt lake systems.

Land management: Wide drainage tracts (unit 2) are mildly susceptible to soil erosion. Impedance of sheet flows can cause water starvation and consequent loss of vigour in vegetation downslope.

Traverse condition summary (49 assessments):
Vegetation – good 12%; fair 53%; poor 23%; very poor 12%.
Soil erosion – nil 92%; slight 2%; minor 6%.

Area mapped as sde: 0.1 km² (0.04% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Small creekline	–	–
2	Wide drainage tract	7	2
3	Narrow drainage tract	1	1
4	Hardpan plain	33	2
5	Loamy plain	9	1
6	Drainage focus	2	–
	Total	52 *	6

* 3 traverse points not assessed for condition.

Ranch land system

Unit area (%)		Landform	Soil	Vegetation
1.	<1%	**Small creeklines** – narrow (<10 m wide) ephemeral creeks with incised channels (to 2 m) emerging from granite uplands.	Juvenile deposits (12).	Close (30-50% PFC) *Acacia aneura* (mulga) shrublands or woodlands on fringing banks (CBKW).
2.	25%	**Wide drainage tracts** – level to very gently inclined broad tracts (to several kilometres wide) receiving distributary flow from unit 1.	Deep red earths or duplex (6a, 8) and shallow hardpan loams and clays (5d, 9a).	Moderately close to close (20-50% PFC) *A. aneura* and *A. tetragonophylla* (curara) tall shrublands or woodlands (DRAS), occasionally with claypan grasses such as *Eriachne flaccida.*
3.	5%	**Narrow drainage tracts** – level to very gently inclined narrow tracts (<500 m wide) often receiving run-on from unit 2.	Deep red earths or shallow clays on hardpan (5d, 9a).	As for unit 2.
4.	50%	**Hardpan plains** – level plains subject to sheet flow adjacent to more concentrated flow zones.	Hardpan loams and shallow red earths on hardpan (5d, 5c).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (HPMS, HCAS). Acacias include *A. grasbyi* (miniritchie), *A. ramulosa* (bowgada), *A. aneura* and *A. tetragonophylla* with non-halophytic (rarely halophytic) undershrubs.
5.	17%	**Loamy plains** – generally level plains subject to diffuse run-on; minor sand banks in lower parts.	Deep sandy red earths and deep red clayey sands (4, 3a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with scattered wanderrie grasses or moderately close *A. linophylla* (wanyu) mid shrubland with *A. aneura* trees (PLMS, MUBW).
6.	3%	**Drainage foci** – irregularly shaped drainage sumps and circular claypans within concentrated flow zones (units 2 and 3).	Deep clay or deep red earths on hardpan (9b, 6a).	Scattered (10-20% PFC) *A. aneura* shrubs, sometimes with dominant grass layer (e.g. *E. flaccida*) (ACGU).

RODERICK LAND SYSTEM (47 km², 0.05% of the survey area)

(after Curry *et al.* 1994)

Saline alluvial plains with numerous drainage foci, supporting halophytic shrublands.

Land type: 17

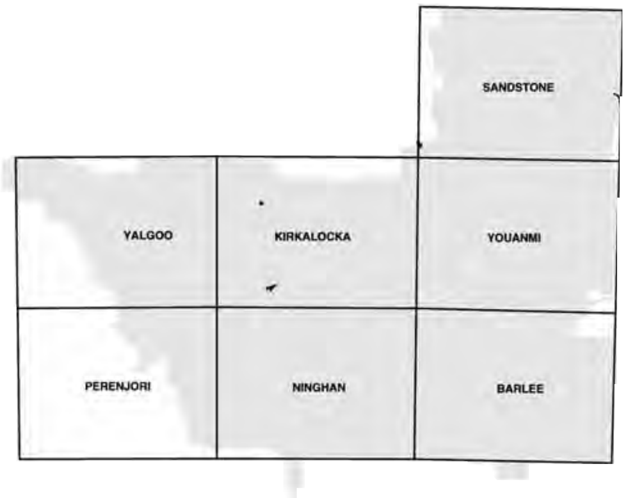
Geology: Quaternary alluvium.

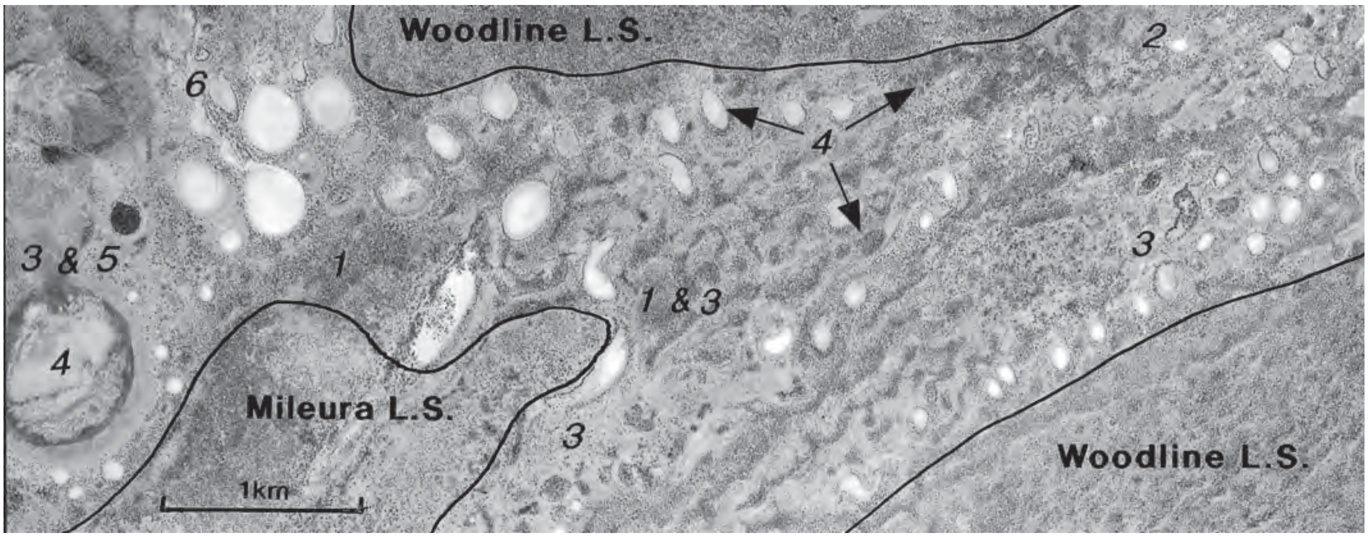
Geomorphology: Depositional surfaces; nearly level alluvial plains with numerous rounded claypans and discrete drainage foci and subject to sheet flow; minor sandy banks and channels. Overall relief mostly <5 m.

Land management: The system supports vegetation types which are highly preferred by grazing animals and are susceptible to overgrazing and degradation; alluvial plains (unit 3) are susceptible to accelerated erosion when degraded. Appropriate land management includes control of total grazing pressure.

Traverse condition summary (10 assessments):
Vegetation – good 30%; fair 62%; poor 8%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank	4	–
2	Hardpan plain	5	1
3	Alluvial plain	3	2
4	Drainage focus	1	–
5	Saline plain	–	–
6	Drainage tract	–	–
	Total	13 *	3

* 3 traverse points not assessed for condition.

Roderick land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Sandy banks** – isolated banks (up to 2 m relief) on units 2 and 3.	Deep red clayey sands, often overlying calcrete (3a).	Scattered (10-20% PFC) tall shrublands including *Acacia victoriae* (prickly acacia), *A. tetragonophylla* (curara), *A. grasbyi* (miniritchie) and *Hakea preissii* (needlebush) with halophytic and non-halophytic low shrubs (SBLS).
2.	5%	**Hardpan plains** – level to very gently inclined plains receiving sheet flow, on margins of system or flanking drainage tracts.	Shallow hardpan loams, red earths or red clayey sands on hardpan (5d, 5c, 2d).	Scattered to moderately close (10-30% PFC) *A. tetragonophylla* or *A. ramulosa* (bowgada) shrublands (HPMS), occasionally with halophytic low shrubs (HMCS).
3.	60%	**Alluvial plains** – extensive, nearly level plains subject to sheet flow.	Shallow duplex on hardpan, occasionally over calcrete (7c).	Very scattered to scattered (2.5-20% PFC) halophytic low shrublands (PXHS), commonly dominated by *Maireana pyramidata* (sago bush) (PSAS).
4.	15%	**Drainage foci** – depositional areas such as claypans and swamps of variable shape and size, but mostly <100 m in diameter and circular to ellipsoid. Larger, irregular ephemeral swamps with gilgai features also occur.	Deep red earths or clays (6a, 9b).	Claypans with no vegetation, other foci with open shrubby *Eriachne flaccida* (claypan grass) tussock grassland (ACGU) or moderately close to close (20-50% PFC) *Acacia distans* (black mulga) low woodlands or tall shrublands (DRAS).
5.	10%	**Saline plains** – level plains in the lower parts of the system, mainly adjacent to unit 6; subject to inundation and water logging.	Deep clay soils on hardpan or calcrete (9b).	Very scattered to scattered (2.5-20% PFC) *Halosarcia* spp. (samphire) low shrublands (SAMP).
6.	5%	**Drainage tracts** – Sluggish, narrow drainage tracts with occasional channels.	Juvenile deposits (12).	Scattered trees and shrubs (10-20% PFC), rushes and grasses.

SHERWOOD LAND SYSTEM (3,458 km², 3.7% of survey area)

(after Mabbutt *et al.* 1963)

Granite breakaways and extensive stony plains with mulga shrublands and minor halophytic shrublands.

Land type: 4

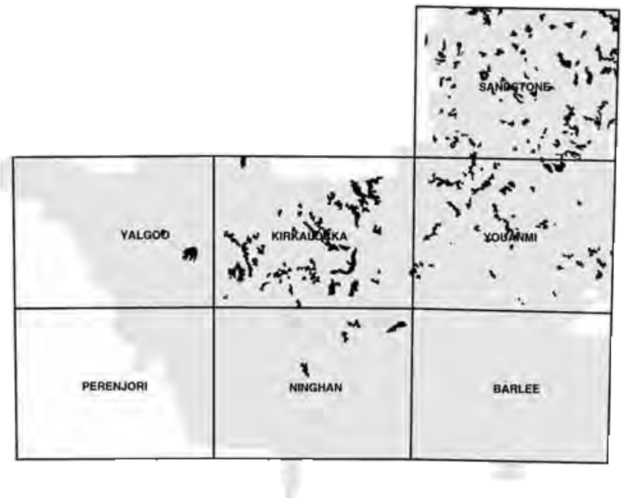
Geology: Archaean granite and gneiss. Tertiary laterite and silcrete, Quaternary colluvium and alluvium.

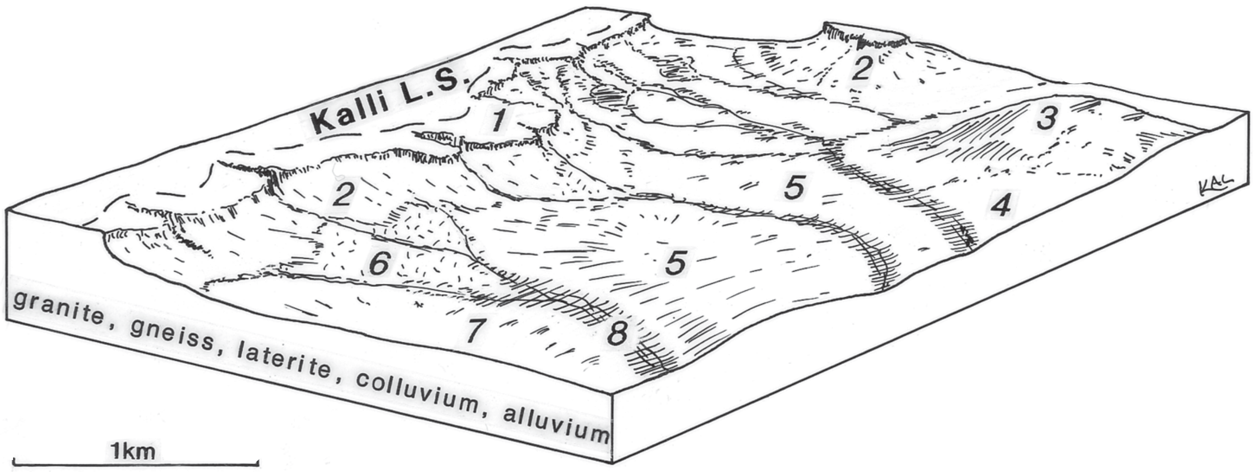
Geomorphology: Predominantly erosional surfaces; stripped plateaux edges and low breakaways (to 20 m relief) with very gently inclined depositional footslopes and plains derived from pallid zone materials; extensive, nearly level to gently undulating plains with mantles of quartz and granite pebbles, traversed by sparse, sub-parallel narrow drainage tracts becoming more dendritic and incised in upper sectors.

Land management: Lower footslopes (unit 2), alluvial plains (unit 6) and drainage tracts (unit 8) generally have fragile soils which are highly susceptible to water erosion. The vegetation on these units is preferentially grazed by introduced and native animals and is susceptible to overgrazing and consequent degradation. Unit 2 is particularly fragile and requires sensitive management to avoid irreversible land degradation.

Traverse condition summary (413 assessments):
Vegetation – good 42%; fair 31%; poor 21%; very poor 6%.
Soil erosion – nil 91%; slight 2%; minor 4%; moderate 3%.

Area mapped as sde: 13.2 km² (0.4% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway/plateau	32	5
2	Lower footslope	45	2
3	Low rise	6	4
4	Gritty-surfaced plain	62	1
5	Stony plain/saline stony plain	118	8
6	Alluvial plain	27	5
7	Hardpan plain/loamy plain	71	–
8	Drainage tract	42	3
	Other	18	–
	Total	421 *	28

* 8 traverse points not assessed for condition.

Sherwood land system

Unit area (%)		Landform	Soil	Vegetation
1.	8%	**Breakaways and plateaux** – low breakaways on granite (3-20 m relief), often with a siliceous duricrust; variably stripped plateaux with abundant lateritic gravel and indurated weathered granite outcrop, moderately inclined to steep escarpments and short pallid zone scree slopes with mantles of quartz and granite pebbles.	Rock outcrop, stony soils and shallow duplex on granite (1, 7a).	Very scattered (2.5-10% PFC) mixed low shrublands, common low shrubs include *Ptilotus obovatus* (cotton bush) and *Micromyrtus sulphurea*, with acacia tall shrubs (BRXS) on plateaux; very scattered (2.5-10% PFC) low shrublands on upper footslopes, with *Ptilotus obovatus* and *Frankenia* spp. (frankenia).
2.	10%	**Lower footslopes** – very gently inclined lower footslopes receiving run-on from unit 1, extending to 1 km, occasionally with a mantle of quartz and granite pebbles.	Shallow duplex on granite (7a).	Scattered (10-20% PFC) halophytic shrublands, common low shrubs include *Atriplex vesicaria* (bladder saltbush) and *Maireana glomerifolia* (ball-leaf bluebush) (BCLS, SBMS, FRAN).
3.	2%	**Low rises** – low rises, granite tors and low hills to 30 m relief with mantles of few to many granite and quartz pebbles and cobbles, and common granite outcrop.	Very shallow coarse red clayey sands on granite (2a).	Very scattered to scattered (2.5-20% PFC) *Acacia quadrimarginea* (granite wattle) tall shrublands (GRHS).
4.	15%	**Gritty-surfaced plains** – level to gently undulating plains with minor outcrop of granite, fringing unit 3.	Shallow coarse red clayey sands or red earths on granite (2a, 5c).	Very scattered to scattered (2.5-20% PFC) *Acacia aneura* (mulga) and *A. quadrimarginea* tall shrublands (SGRS) occasionally with wanderrie grasses.
5.	35%	**Stony plains/saline stony plains** – broad, level to gently undulating plains with mantles of few to abundant granite pebbles and cobbles, and minor granite outcrop.	Very shallow red clayey sand on granite, occasionally shallow duplex on granite (2a, 7a).	Scattered (10-20% PFC) acacia - eremophila shrublands (SAES) or scattered acacia shrublands (SGRS), occasionally very scattered to scattered (2.5-20% PFC) *Maireana* spp. (bluebush) low shrublands (SBMS).
6.	5%	**Alluvial plains** – very gently inclined plains receiving sheet flow from unit 2, occasional shallow channels.	Shallow duplex on granite or hardpan (7a, 7c).	Scattered (10-20% PFC) halophytic low shrublands often with *Maireana pyramidata* (sago bush) (PSAS) dominant; occasionally with *Atriplex vesicaria* (BLSS), *Atriplex bunburyana* (silver saltbush (SSAS).
7.	15%	**Hardpan plains/loamy plains** – level to very gently inclined plains, subject to sheet flow, occasionally with a mantle of fine ironstone gravel.	Shallow hardpan loams or red earths on hardpan (5d, 5c).	Scattered (10-20% PFC) tall *A. aneura* shrublands (HPMS, PLMS, MUBW).
8.	10%	**Drainage tracts** – channelled or unchannelled zones receiving concentrated flow, generally less than 500 m wide. Channels to 10 m wide and mostly <1 m deep.	Shallow duplex or red earths on granite (7a, 5c).	Moderately close (20-30% PFC) acacia tall shrublands (DRAS, HPCS). Dominant acacia species may be *A. aneura, A. acuminata* subsp. *burkittii* (fine-leaf jam) or *A. tetragonophylla* (curara).

SINGLETON LAND SYSTEM (238 km², 0.3% of the survey area)

Rugged greenstone ranges with dense casuarina and acacia shrublands.

Land type: 2

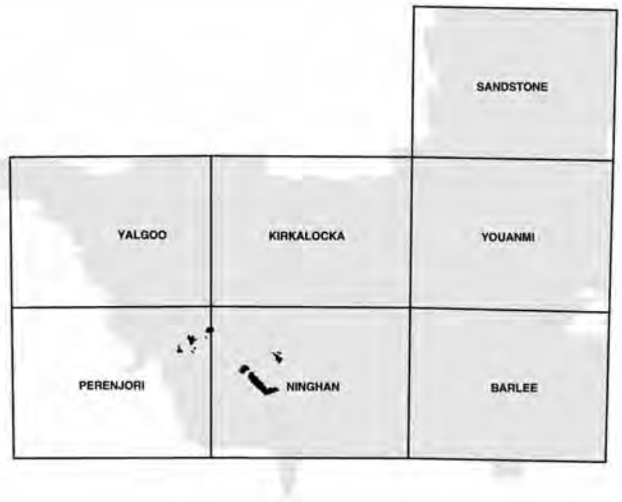
Geology: Archaean mafic and ultramafic rocks, including gabbro and basalt agglomerates.

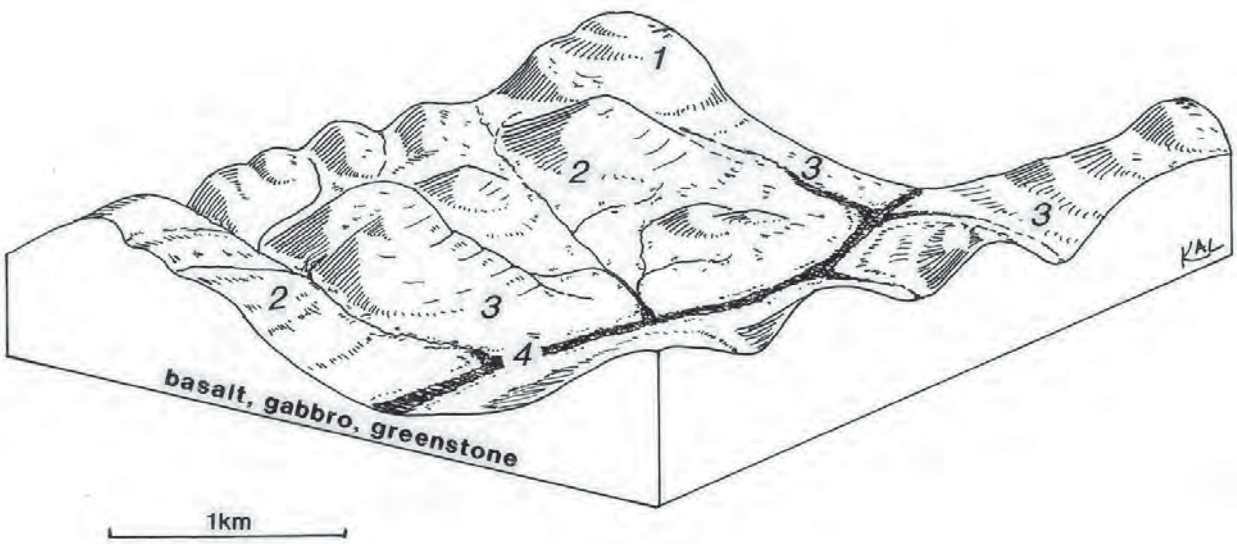
Geomorphology: Erosional surfaces; hills on mafic and ultramafic rocks with gently to moderately inclined hillslopes and narrow drainage tracts; relief to 120 m.

Land management: Rugged hills mostly poorly accessible; stone mantles protect most of this land system against soil erosion.

Traverse condition summary (26 assessments):
Vegetation – good 61%; fair 31%; poor 8%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hillcrest	3	–
2	Hillslope	7	2
3	Footslope	12	–
4	Drainage line	4	1
	Total	26	3

Singleton land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Hillcrests** – rounded crests and summits of greenstone hills and ridges with mantles of abundant cobbles and rocks and exposed bedrock.	Stony soils (1).	Moderately close (20-30% PFC) *Acacia quadrimarginea* (granite wattle), *A. acuminata* subsp. *burkittii* (fine-leaf jam) tall shrublands (SIAS, GHAS) or moderately close *Allocasuarina campestris-Acacia* spp. woodlands (GHMW).
2.	30%	**Hillslopes** – gently inclined to steep slopes of greenstone hills with mantles of few to abundant metamorphic pebbles and cobbles and exposed bedrock.	Stony soils and shallow red earths (1, 5c).	Moderately close (20-30% PFC) *Acacia quadrimarginea-A. acuminata* subsp. *burkittii* tall shrublands (SIAS, GHAS) or moderately close *Allocasuarina campestris-Acacia* spp. woodlands (GHMW).
3.	50%	**Footslopes** – gently inclined lower footslopes and stony plains with mantles of variably dense pebbles and cobbles.	Shallow duplex or red earths on greenstone (7b, 5c).	As for units 1 and 2; also occasional pockets of *Eucalyptus salmonophloia* (salmon gum) woodland with *Atriplex* spp (saltbush) undershrubs (PECW).
4.	10%	**Drainage lines** – narrow creeklines draining to lower shallow valleys; mantles of variably dense pebbles and cobbles.	Deep duplex on basalt or greenstone (8).	Closed (>50% PFC) *Allocasuarina tessellata* tall shrublands in upper parts; elsewhere *A. campestris-Acacia* spp. woodlands or tall shrublands (GHMW).

S

SKIPPER LAND SYSTEM (19 km², 0.02% of the survey area)

Alluvial plains and saline flats interspersed with sandy banks, supporting mixed halophytic shrublands (a very small system found at only one location in the centre of the survey area).

Land type: 17

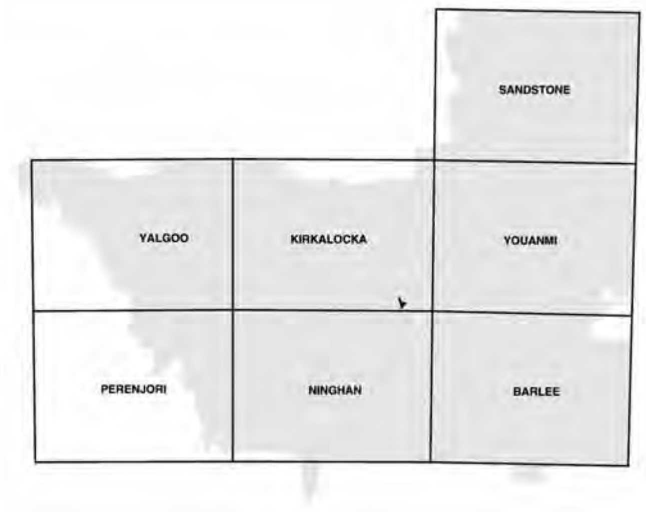
Geology: Quaternary alluvium, clay and sand.

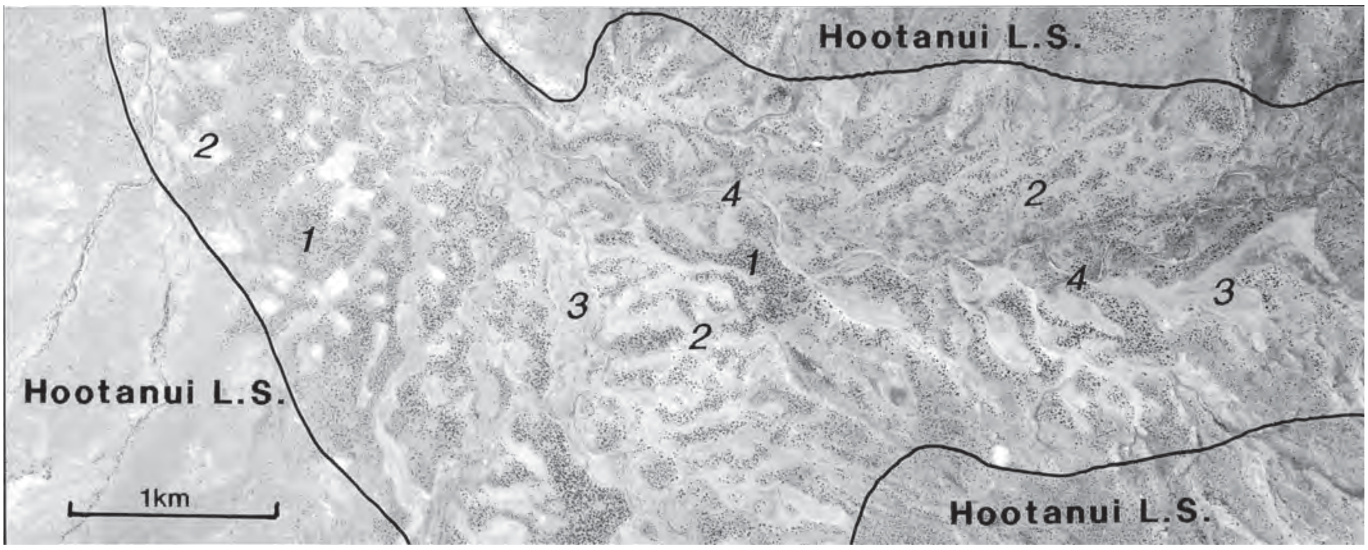
Geomorphology: Depositional surfaces; very gently inclined alluvial plains with reticulate sandy banks and sluggish through flowing drainage tracts with meandering channels.

Land management: Sandy banks (unit 1) and other units with duplex soils are mildly susceptible to erosion if vegetative cover is depleted, some susceptibility to shrub invasion in degraded areas.

Traverse condition summary (2 assessments):
Vegetation – insufficient assessments.
Soil erosion – insufficient assessments.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank	1	2
2	Saline alluvial plain	–	–
3	Highly saline flat	–	1
4	Drainage tract	1	–
	Total	2	3

Skipper land system

Unit area (%)		Landform	Soil	Vegetation
1.	30%	**Sandy banks** – diffuse, reticulate sandy banks to 1 km in extent and raised to 2 m above surrounding plains.	Shallow red clayey sands and deep duplex soils on hardpan (2d, 8).	Very scattered to scattered (2.5-20% PFC) mixed height shrublands with *Eremophila miniata* (kopi poverty bush), *Hakea preissii* (needle bush), *Atriplex bunburyana* (silver saltbush) and numerous other halophytic low shrubs (SBLS, SSAS).
2.	20%	**Saline alluvial plains** – narrow (to 200 m wide) nearly level plains between sandy banks, subject to sheet flow.	Deep duplex soils (8).	Very scattered to scattered (2.5-20% PFC) low shrublands of *Atriplex, Maireana* and *Frankenia* spp. (saltbush, bluebush and frankenia) (PXHS).
3.	30%	**Highly saline flats** – narrow central flats between sandy banks or alluvial plains, subject to inundation.	Juvenile and clay soils (highly saline) (9b, 12).	Scattered (2.5-20% PFC) *Halosarcia* spp. (samphire) low shrublands (SAMP).
4.	20%	**Drainage tracts** – tracts to 300 m wide with weakly incised meandering channels.	Juvenile and clay soils (highly saline) (9b, 12).	Scattered *Halosarcia* spp. low shrublands (SAMP).

STEER LAND SYSTEM (133 km², 0.1% of the survey area)

(after Pringle *et al.* 1994)

Gravelly alluvial plains with prominent small drainage foci supporting halophytic shrublands.

Land type: 17

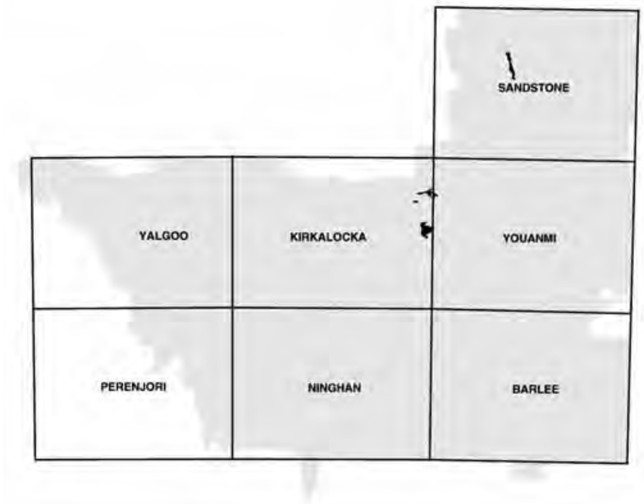
Geology: Quaternary alluvium, colluvium and eluvium, minor Tertiary ferruginous duricrust.

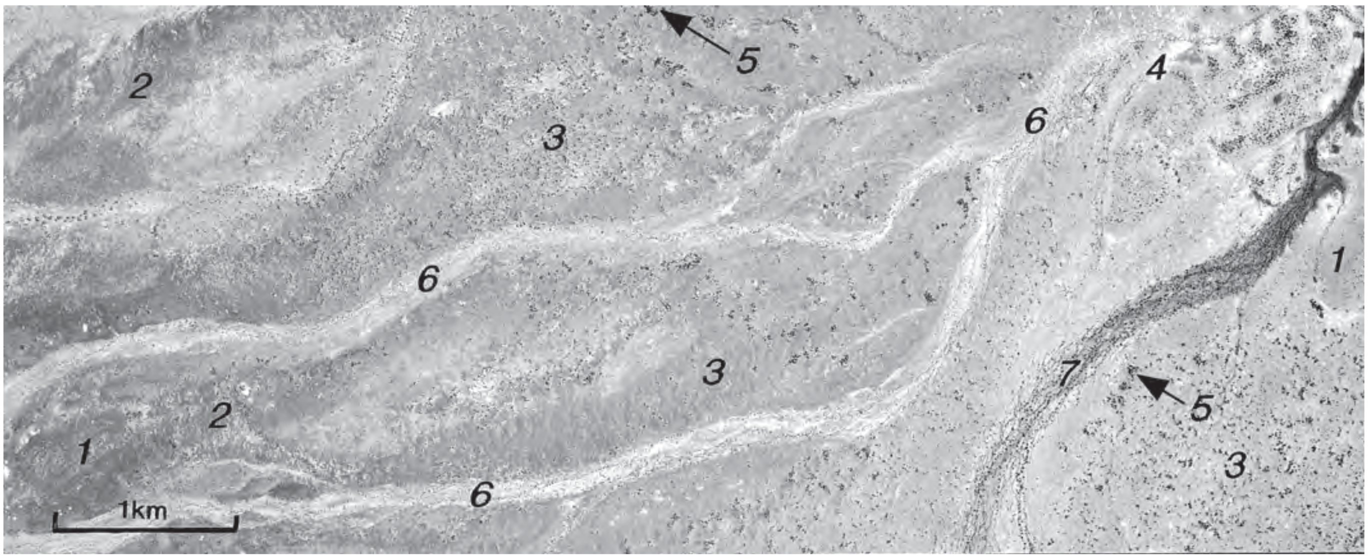
Geomorphology: Depositional surfaces; alluvial plains with fine ferruginous gravel mantles and prominent circular drainage foci, receiving run-on from adjacent limonitic or greenstone hills, also low rises with limonitic pebble mantles and central drainage tracts with some channelled flow.

Land management: This land system is generally not susceptible to erosion, partly as a consequence of protective stone and gravel soil mantles. However, unprotected areas on alluvial plains (unit 3) and more particularly on drainage floors (unit 6) are susceptible to water erosion. The vegetation of this system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (10 assessments):
Vegetation – good 30%; fair 20%; poor 20%; very poor 30%.
Soil erosion – nil 40%; slight 10%; minor 20%; moderate 10%; severe 20%.

Area mapped as sde: 1.2 km² (0.9% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Low rise	–	–
2	Stony plain/saline stony plain	2	–
3	Alluvial plain	7	1
4	Saline alluvial plain	–	–
5	Drainage focus	–	2
6	Wide drainage floor	1	–
7	Creekline	–	–
	Other	1	–
	Total	11 *	3

* 1 traverse point not assessed for condition.

Steer land system

Unit area (%)		Landform	Soil	Vegetation
1.	5%	**Low rises** – low rises with limonitic pebble mantles, relief to 5 m.	Stony soils (1).	Very scattered to scattered (2.5-20% PFC) mixed shrublands (SIMS, USBS).
2.	10%	**Stony plains/saline stony plains** – gently undulating plains with quartz and ironstone pebble mantles, slightly above unit 3.	Shallow duplex on greenstone (7b).	Very scattered to scattered (2.5-20% PFC) mixed halophytic and non-halophytic low shrublands (USBS, SBMS) or scattered (10-20% PFC) acacia-eremophila shrublands (SAES).
3.	55%	**Alluvial plains** – level to very gently inclined plains receiving sheet flow, generally fine ferruginous gravel mantle, occasionally also with quartz coarse fragments.	Shallow duplex on hardpan or deep clays with a stony mantle (7c, 9b).	Scattered (10-20% PFC) mixed halophytic low shrublands or very scattered to scattered (2.5-20% PFC) *Maireana* spp. (bluebush) low shrublands (PXHS, SBMS).
4.	5%	**Saline alluvial plains** – low lying level plains with mantles of fine ferruginous gravel.	Deep clays (9b).	Scattered (10-20% PFC) *Halosarcia* spp. (samphire) low shrublands (SAMP).
5.	2%	**Drainage foci** – foci to 250 m in diameter.	Deep clays (9b).	Moderately close to close (20-50% PFC) acacia tall shrublands (DRAS) occasionally with mixed halophytic and non-halophytic low shrubs (DMCS).
6.	22%	**Drainage floors** – generally wide (>500 m) drainage floors with shallow channels in lowest parts.	Deep duplexes (8).	Scattered (10-20% PFC) mixed halophytic low shrublands, occasionally with *Atriplex bunburyana* (silver saltbush) dominant (PXHS, SSAS) or moderately close (20-30% PFC) acacia tall shrublands (DRAS, DMCS).
7.	1%	**Creeklines** – occasional creeklines to 20 m wide.	Juvenile deposits (12).	Fringing scattered to moderately close (10-30% PFC) woodlands (CBKW).

TALLERING LAND SYSTEM (329 km², 0.3% of survey area)

Prominent ridges and hills of banded ironstone, dolerite and sedimentary rocks supporting bowgada and other acacia shrublands.

Land type: 2

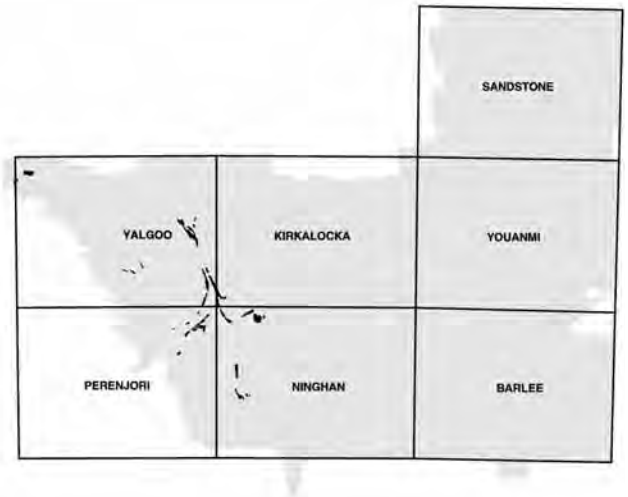
Geology: Archaean banded ironstone formation, dolerite, schist and sedimentary rocks, Cainozoic laterite and colluvium.

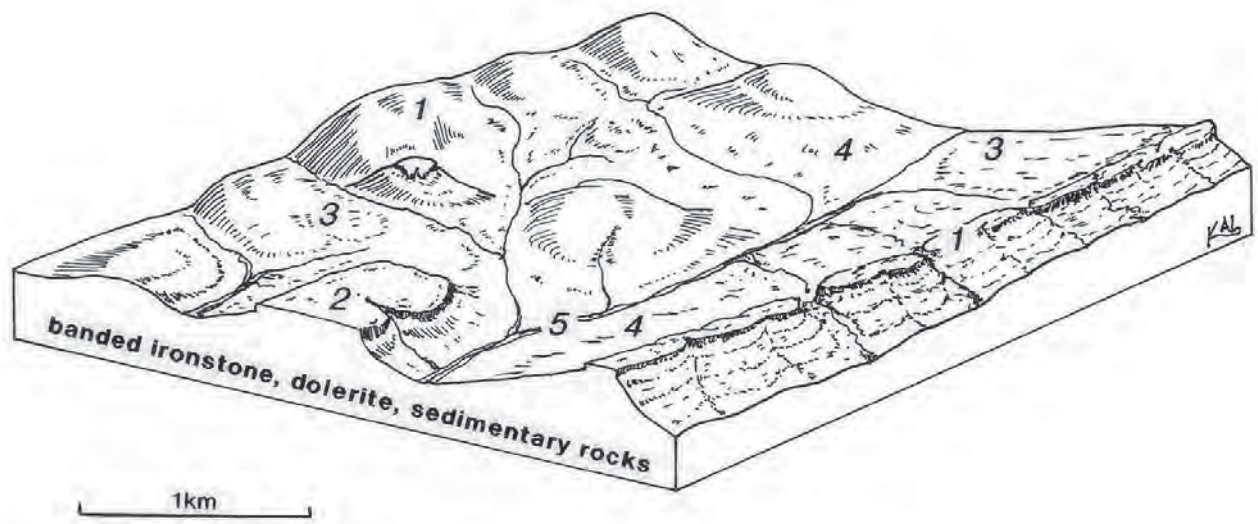
Geomorphology: Erosional surfaces; linear ridges up to 8 km long and low hills and rises with gently inclined footslopes, minor gravelly plains and narrow drainage floors with channels. Relief up to 200m but commonly much less.

Land management: Stone mantles provide effective protection against soil erosion; disturbance or removal of stone mantles may initiate erosion.

Traverse condition summary (29 assessments):
Vegetation – good 69%; fair 31%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Ridge/hill	–	2
2	Stripped surface	–	1
3	Hillslope	14	7
4	Stony plain/gravelly plain	11	–
5	Narrow drainage tract	–	1
	Other	4	1
	Total	29	12

Tallering land system

Unit	area (%)	Landform	Soil	Vegetation
1.	20%	**Ridges and hills** – generally linear ridges of banded iron formation and hills on dolerite, schist or sedimentary rocks, mantles of abundant platy cobbles and stones; relief to 200 m but commonly much less.	Shallow stony red earths (5b).	Scattered to moderately close (10-30% PFC) tall shrublands of *Acacia ramulosa* (bowgada) and other acacias with undershrubs such as *Thryptomene* and *Eriostemon* species (IRMS)
2.	2%	**Stripped surfaces** – residual duricrust surfaces and occasional very low breakaways downslope of unit 1, mantles of abundant ironstone and lateritic gravels and outcrop.	Stony soils (1)	Very scattered (2.5-10% PFC) mixed height shrublands with *A. ramulosa* and well developed non-halophytic understoreys (BRXS).
3.	58%	**Hillslopes** – upper and lower slopes to ridges and hills, moderately to very gently inclined; mantles of abundant angular and platy pebbles and cobbles of banded ironstone and metasediments.	Shallow red earths and stony red earths (5c, 5b).	Scattered to moderately close (10-30% PFC) tall shrublands of *A. ramulosa* and other acacias. Understorey species include *Eremophila* spp., *Ptilotus obovatus* (cotton bush), *Thryptomene* spp. and *Eriostemon* spp. (SIAS).
4.	10%	**Stony plains/gravelly plains** – very gently inclined plains and low stony rises, mantles of abundant ironstone and metasediment pebbles and cobbles.	Shallow stony red earths and red clayey sands with ferruginous gravel (5b, 2b).	Scattered to moderately close (10-30% PFC) tall shrublands of *A. ramulosa* and other acacias. Undershrubs include *Eremophila* spp., *Ptilotus obovatus, Thryptomene* spp. and *Eriostemon* spp. (SIAS, LACS).
5.	10%	**Narrow drainage tracts** – narrow (<50 m) linear drainage zones with minor channels, angular pebbles and cobbles in channels, elsewhere little stony mantle.	Deep red clayey sands (3a).	Scattered to moderately close (10-30% PFC) tall shrublands of *A. ramulosa* and other acacias with *Eremophila forrestii* (Wilcox bush) and *Ptilotus obovatus* low shrubs (SIAS).

TANGO LAND SYSTEM (86 km^2, 0.1% of the survey area)

Saline hardpan plains with ironstone gravel mantles supporting mulga tall shrublands with halophytic and non-halophytic understorey shrubs.

Land type: 15

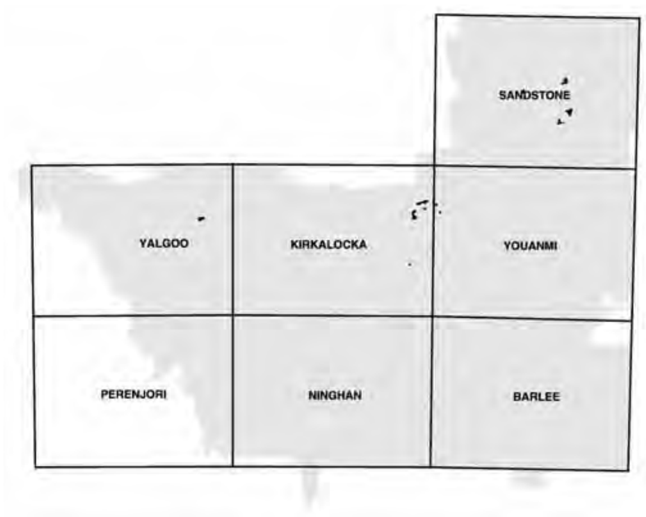
Geology: Cemented Quaternary alluvium derived mainly from greenstone.

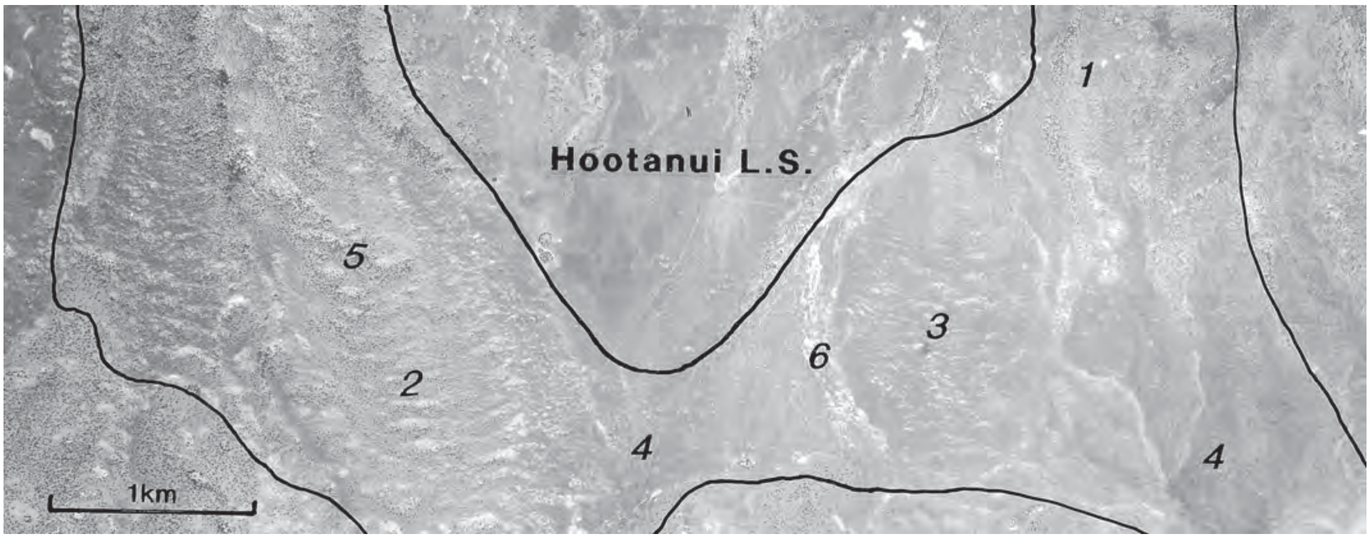
Geomorphology: Depositional surfaces; level to gently inclined plains on hardpan with mantles of fine ironstone and occasionally quartz gravel, subject to sheet flow; also drainage tracts receiving more concentrated run-on, occasionally with shallow channels incised into hardpan.

Land management: Impedance to natural sheet flow can initiate soil erosion and cause water starvation and consequent loss of vigour in vegetation downslope. Gravel mantles provide some protection against soil erosion. Some vegetation types are preferentially grazed and prone to degradation unless grazing pressure is controlled.

Traverse condition summary (25 assessments):
Vegetation – good 24%; fair 36%; poor 20%; very poor 20%.
Soil erosion – nil 80%; slight 4%; minor 12%; moderate 4%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Stony hardpan plain	1	2
2	Hardpan plain	6	–
3	Saline stony plain	5	–
4	Saline hardpan plain	11	3
5	Sandy bank	–	–
6	Drainage tract	2	1
	Total	25	6

Tango land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Stony hardpan plains** – minor very gently inclined upper plains with mantles of ironstone pebbles and quartz, subject to sheet flow, vegetation may be weakly groved.	Shallow red earths on hardpan in intergroves (5c), deep red earths (occasionally on hardpan) in groves (6a).	Very scattered (2.5-10% PFC) medium height or tall shrublands of *Acacia aneura* (mulga) (HPMS, SAES); moderately close (20-30% PFC) *A. aneura* tall shrublands in groves (GRMU)
2.	35%	**Hardpan plains** – nearly level plains with or without mantles of ironstone pebbles, subject to sheet flow, vegetation may be weakly groved.	As for unit 1.	Scattered (10-20% PFC) tall shrublands of *A. aneura* with non-halophytic understoreys (HPMS, LHMS); moderately close (20-30% PFC) *A. aneura* tall shrublands in groves (GRMU).
3.	35%	**Saline hardpan plains** – nearly level plains with mantles of variable density ironstone pebbles, subject to sheet flow.	As for unit 1.	Scattered (10-20% PFC) tall shrublands of *Acacia aneura* with halophytic undershrubs in intergroves (HMCS); moderately close (20-30% PFC) *A. aneura, A. pruinocarpa* (gidgee) in groves (GRMU). Occasionally halophytic low shrublands with acacia overstoreys (ASWS).
4.	15%	**Saline stony plains** – level plains with mantles of abundant ironstone pebbles.	Shallow red earths (5c).	Scattered (10-20% PFC) halophytic low shrublands of Maireana spp. (bluebush) with occasional tall shrubs such as *A. tetragonophylla* (curara) and *A. eremaea* (snakewood) (SBMS).
5.	2%	**Sandy banks** – occasional irregular low (<50 cm high) banks with mantles of fine ironstone gravel, on units 2 and 3.	Deep red clayey sands (3a).	Scattered (10-20% PFC) acacia tall shrublands with wanderrie grasses (WABS).
6.	8%	**Drainage tracts** – sparse (usually <500 m wide) tracts receiving concentrated run-on, occasionally with shallow channels incised into hardpan	Red earths on hardpan at variable depth (5c, 6a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands (DRAS).

TEALTOO LAND SYSTEM (693 km², 0.7% of the survey area)

Level to gently undulating loamy plains with fine ironstone lag gravel supporting dense acacia shrublands.

Land type: 16

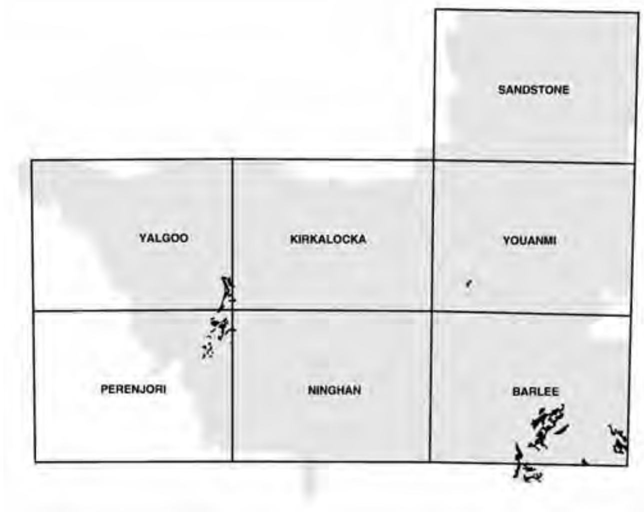
Geology: Quaternary sands, Cainozoic alluvial and colluvial deposits and Tertiary ferruginised profiles.

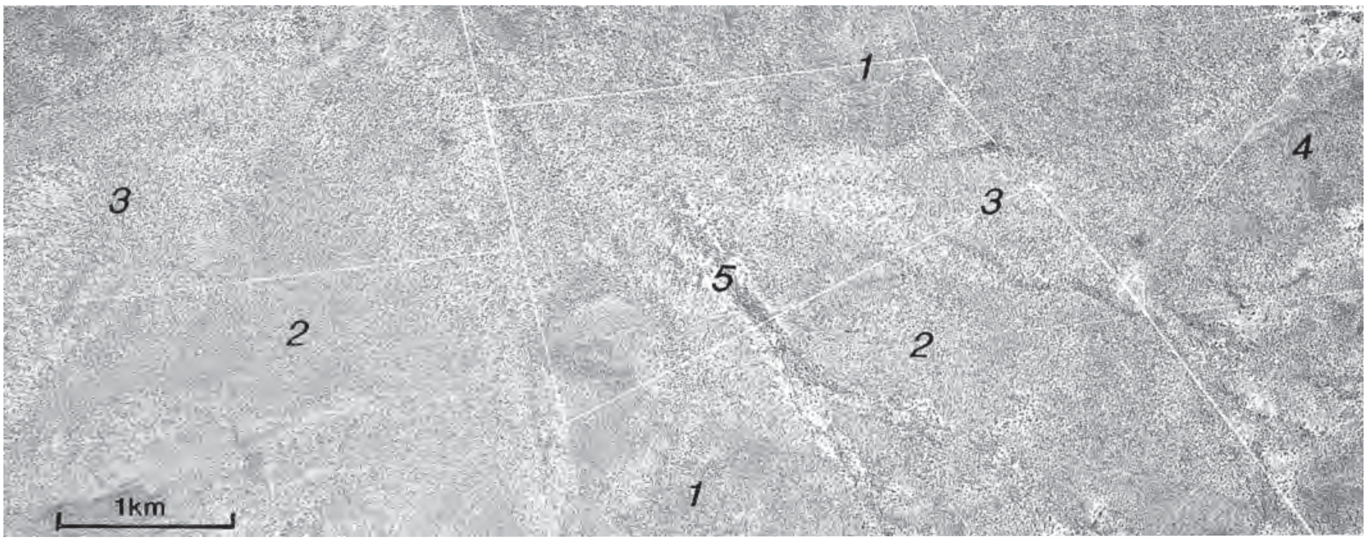
Geomorphology: Depositional surfaces; level plains and sandy tracts with gravelly mantles and alluvial plains receiving more concentrated flow.

Land management: The vegetation types on this system are not particularly preferred by grazing animals and are generally not degraded. The system is not generally prone to soil erosion.

Traverse condition summary (96 assessments):
Vegetation – good 56%; fair 32%; poor 12%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Stony plain	13	–
2	Gravelly plain/loamy plain	60	8
3	Gravelly hardpan plain	19	2
4	Gravelly sand sheet	7	2
5	Alluvial plain	3	–
	Total	102 *	12

* 6 traverse points not assessed for condition.

Tealtoo land system

Unit area (%)		Landform	Soil	Vegetation
1.	10%	**Stony plains** – very gently inclined upper plains with mantles of abundant ironstone gravel and pebbles.	Shallow red earths on ironstone gravel or parent rock (5c).	Moderately close (20-30% PFC) acacia tall shrublands (SIAS).
2	60%	**Gravelly plains/loamy plains** – level plains with mantles of few to abundant ironstone gravel.	Deep red earths on ironstone gravel or hardpan at variable depth (6a).	Moderately close (20-30% PFC) acacia tall shrublands with *Acacia aneura* (mulga) trees and *A. ramulosa* (bowgada) (MUBW, PLMS), or eucalypt mallee overstorey (PYAW), or close (30-50% PFC) *Allocasuarina eriochlamys* subsp. *eriochlamys* - *A. coolgardiensis* (sugar brother) tall shrubland with low and mid myrtaceous shrubs (LACS).
3.	20%	**Gravelly hardpan plains** – level plains with fine ironstone gravel mantles.	Shallow hardpan loams or red earths on hardpan (5d, 5c).	Scattered to moderately close (10-30% PFC) acacia tall shrublands including *A. aneura, A. ramulosa* (bowgada), *A. linophylla* (wanyu) and *A. acuminata* subsp. *burkittii* (fine-leaf jam) (HPMS, LACS, MUBW).
4.	8%	**Gravelly sand sheets** – level sandy tracts with mantles of common to abundant fine ironstone gravel.	Shallow red clayey sands with ferruginous gravel on hardpan or gravel (2b).	Moderately close (20-30% PFC) acacia tall shrublands with mallee eucalypts. Understorey species include *Prostanthera, Phebalium* and *Mirbelia* (MAAS, SACS).
5.	2%	**Alluvial plains** – level plains receiving more concentrated flow, mantles of common fine ironstone gravel.	Deep red earths (6a).	Scattered (10-20% PFC) acacia tall shrublands with *Eucalyptus loxophleba* (York gum) overstorey and *Atriplex bunburyana* (silver saltbush) understorey (PECW) or moderately close (20-30% PFC) acacia tall shrublands (DRAS).

TEUTONIC LAND SYSTEM (78 km^2, 0.1% of the survey area)

(after Pringle *et al.* 1994)

Hills and stony plains on acid volcanic rocks supporting acacia shrublands.

Land type: 1

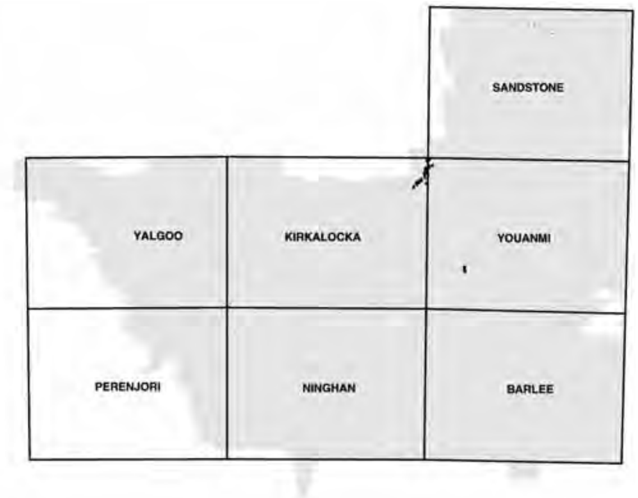
Geology: Archaean felsic extrusive and intrusive rocks with occasional quartz veins and minor Quaternary colluvium and alluvium

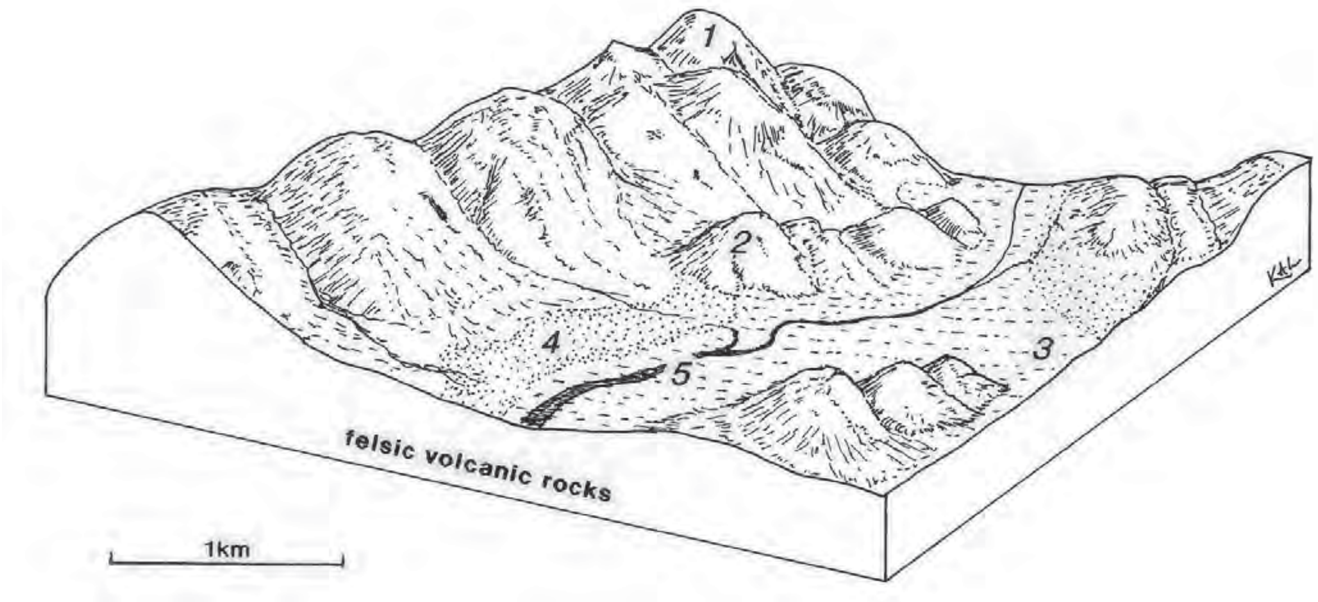
Geomorphology: Hills to 60 m relief, gently inclined hillslopes and lower plains with pebble mantles and narrow incised drainage floors.

Land management: This land system is generally not susceptible to soil erosion partly as a consequence of extensive stone mantles.

Traverse condition summary (4 assessments):
Vegetation – insufficient assessments.
Soil erosion – insufficient assessments.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hill, hillslope	2	3
2	Low rise	–	–
3	Stony plain	–	–
4	Stony saline plain	–	1
5	Narrow drainage tract	1	–
	Other	2	–
	Total	5 *	4

* 1 traverse point not assessed for condition.

Teutonic land system

Unit area (%)		Landform	Soil	Vegetation
1.	40%	**Hills** – low hills and ridges (occasionally to 60 m relief but usually much less) with gently inclined stony footslopes, abundant quartz mantles and minor outcrop of quartz, schistose felsic rocks and gabbro.	Stony soils (1).	Scattered (10-20% PFC) acacia tall shrublands or low shrublands of *Ptilotus obovatus* (cotton bush) with acacia overstoreys (SIAS, GHAS).
2.	15%	**Low rises** – low gently undulating rises (<10 m relief) with occasional ferruginous duricrust.	Stony soils (1).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrublands (SIMS).
3.	30%	**Stony plains** – level to very gently inclined plains with mantles of abundant quartz and other pebbles.	Shallow red earths on greenstone (5c).	Scattered (10-20% PFC) *A. aneura*-*Eremophila* spp. (poverty bushes) tall shrublands (SAES).
4.	5%	**Saline stony plains** – occasional narrow, level to gently inclined plains with mantles of abundant quartz and other pebbles.	Shallow duplex and red earths on greenstone (7b, 5c).	Scattered (10-30% PFC) *Maireana* spp. (bluebush) halophytic low shrublands, (SBMS, occasionally USBS).
5.	10%	**Narrow drainage tracts** – sparse narrow (usually <50 m wide) drainage floors with incised shallow channels.	Shallow clays or red earths (9a, 5c).	Scattered to moderately close (10-30% PFC) *Acacia aneura* (mulga) tall shrublands (DRAS).

TINDALARRA LAND SYSTEM (4,349 km^2, 4.6% of survey area)

(after Curry *et al.* 1994)

Hardpan plains supporting acacia shrublands with sparse drainage channels and associated drainage floors supporting saltbush/bluebush shrubs under snakewood.

Land type: 13

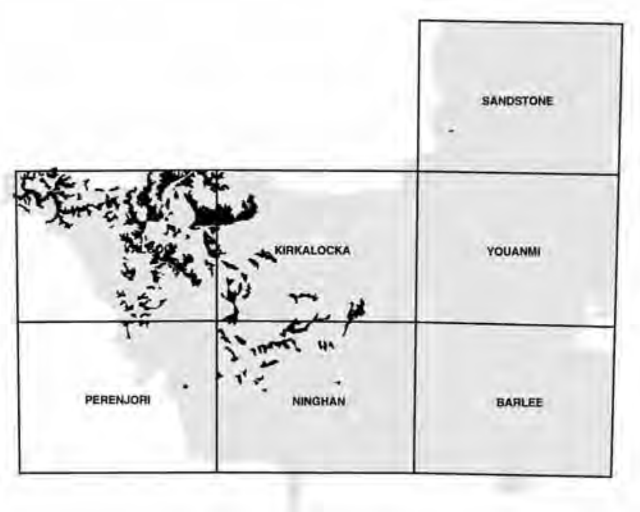
Geology: Quaternary alluvium and hardpan.

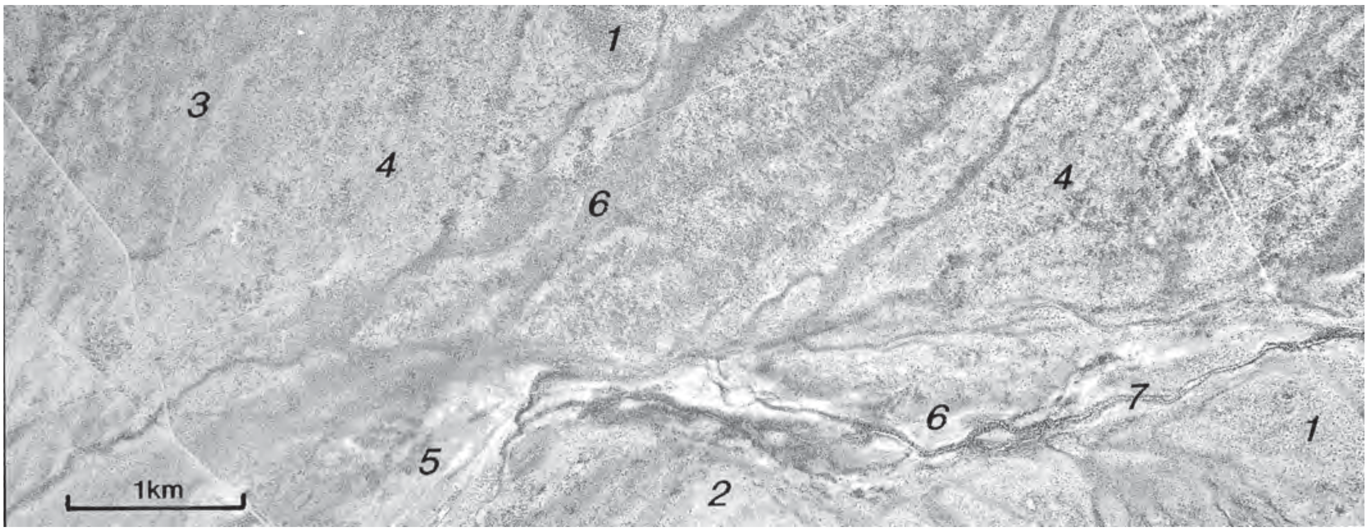
Geomorphology: Depositional surfaces; very restricted gently sloping upper plains on granite, broad nearly level plains up to 10 km or more in extent subject to diffuse sheet flow, occasional low wanderrie banks; narrow floodplains carrying more concentrated sheet flow and flanking concentrated drainage tracts with incised channels; relief mostly <5 m.

Land management: Impedance of sheet flows on units 3 & 4 can cause water starvation and consequent loss of vigour in vegetation downslope. Halophytic low shrublands on alluvial plains and drainage tracts (units 5 & 6) are often degraded due to preferential overgrazing and are moderately susceptible to accelerated erosion.

Traverse condition summary (710 assessments): Vegetation – good 17%; fair 45%; poor 30%; very poor 8%. Soil erosion – nil 89%; slight 3%; minor 4%; moderate 3%; severe 1%.

Area mapped as sde: 14 km^2 (0.3% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Sandy bank/sand sheet	15	–
2	Gritty surfaced plain	15	3
3	Loamy plain	73	3
4	Hardpan plain	462	9
5	Alluvial plain	66	4
6	Drainage tract	80	5
7	Creekline/channel	2	2
	Other	3	–
	Total	716 *	24

* 6 traverse points not assessed for condition.

Tindalarra land system

Unit area (%)		Landform	Soil	Vegetation
1.	3%	**Sandy banks/sand sheets** – isolated sandy banks and sandplain remnants to 1 km in extent.	Deep red clayey sands (3a).	Scattered (10-20% PFC) acacia tall shrublands with low shrubs such as *Eremophila forrestii* (Wilcox bush) and wanderrie grasses (WABS, SWGS).
2.	1%	**Gritty surfaced plains on granite** – restricted, very gently inclined plains with occasional granite outcrops	Shallow coarse red clayey sands on granite (2a).	Moderately close (20-30% PFC) shrublands of acacias and *Hakea recurva* (stand back) (SGRS).
3.	10%	**Loamy plains** – very gently inclined plains extending for up to 3 km, subject to diffuse sheet flow.	Mostly deep red clayey sands or red earths on hardpan (3a, 6a).	Moderately close (20-30% PFC) tall shrublands of *Acacia ramulosa* (bowgada) and other acacias with low shrubs such as *Eremophila forrestii* and sparse wanderrie grasses (MUBW, PLMS, HCAS).
4.	70%	**Hardpan plains** – very gently inclined broad plains extending for up to 8 km, occasionally with a mantle of few quartz or ironstone pebbles, subject to sheet flow.	Deep red earths or shallow hardpan loams on hardpan (6a, 5d).	Scattered to moderately close tall (10-30% PFC) shrublands co-dominated by *A. ramulosa*, *A. aneura* (mulga), *A. grasbyi* (miniritchie) and *A. acuminata* subsp. *burkittii* (fine-leaf jam) (HPMS, HCAS).
5.	5%	**Alluvial plains** – very gently inclined flood plains as inclusions (generally <2 km in extent) in unit 4 or associated with unit 6.	Shallow duplex soils and hardpan loams (7c, 5d) or red clayey sands (2d).	Very scattered to scattered (2.5-20% PFC) tall shrublands of *A. eremaea* (snakewood) with prominent undershrubs of frankenia and bluebush or low shrublands of frankenia and bluebush (ASWS, FRAN).
6.	10%	**Drainage tracts** – very gently inclined tributary flood plains, up to 1 km wide flanking creek channels.	Shallow hardpan loams, clays (5d, 7a) and red clayey sands on hardpan (2d).	Scattered (10-20% PFC) tall and low shrublands dominated by *A. eremaea,* frankenia and bluebush (ASWS) occasionally with *Eucalyptus loxophleba*, (York gum) trees. Also moderately close to close tall shrublands of *A. tetragonophylla* (curara) and other acacias (DRAS).
7.	1%	**Creeklines and channels** – Creeklines receiving flow from lower parts of unit 4 and becoming larger and more incised (up to 50 m wide and 2 m deep) as they pass through units 5 and 6. Also major channels to 100 m wide (e.g. Greenough River).	Juvenile deposits (12).	Moderately close (20-30% PFC) fringing woodlands or tall shrublands of acacias, *Casuarina obesa* (swamp oak), *Callistemon phoeniceus* (lesser bottlebrush) (CBKW, CBBS).

TYRRELL LAND SYSTEM (1,960 km^2, 2.1% of the survey area)

Extensive sandplain with mallees, wattles, heath and spinifex.

Land type: 10

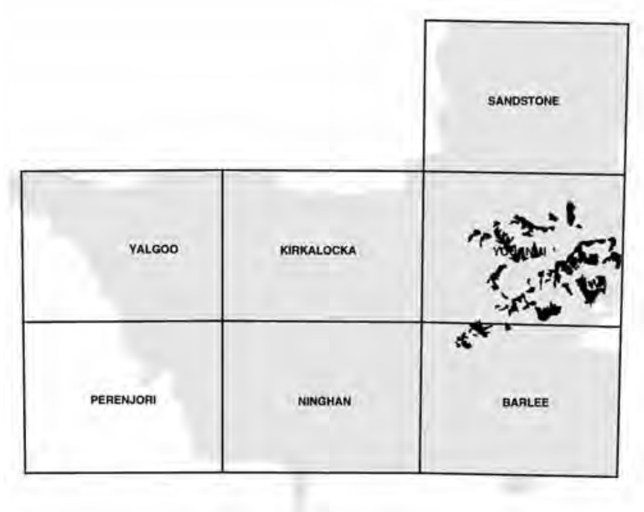
Geology: Predominantly Quaternary sand with isolated areas of Quaternary alluvium.

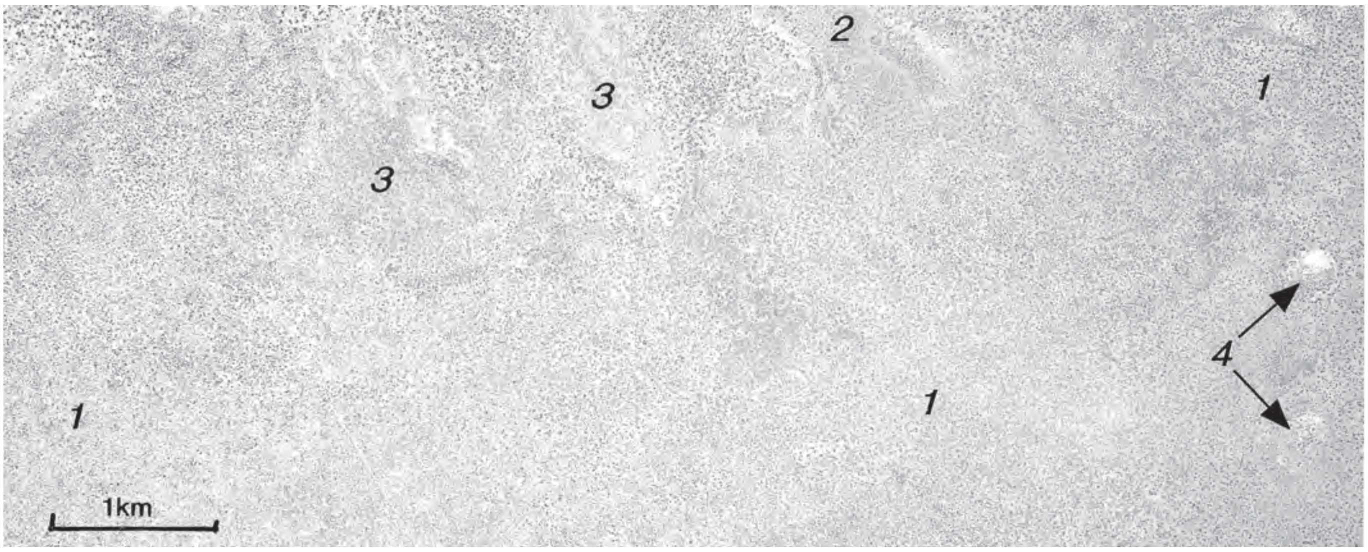
Geomorphology: Depositional surfaces; extensive nearly level sand sheet with isolated dunes and minor areas receiving run-on from adjacent land systems.

Land management: In areas with a well developed hummock grass layer wildfires can cause damage to infrastructure and adjacent, less fire-adapted habitats. Wind erosion following fires is usually only a minor, temporary problem until vegetation cover returns.

Traverse condition summary (177 assessments):
Vegetation – good 80%; fair 15%; poor 4%; very poor 1%
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sand sheet	143	6
2	Sand dune	–	1
3	Loamy plain	31	1
4	Drainage focus	–	1
	Other	6	–
	Total	180 *	9

* 3 traverse points not assessed for condition.

Tyrrell land system

Unit area (%)	Landform	Soil	Vegetation
1. 80%	**Sand sheets** – extensive almost level plains, occasionally more than 10 km wide.	Deep red clayey sands (3a).	Spinifex hummock grasslands with generally very variable, sometimes dominant, acacia tall shrubs and mallees, and occasional *Eucalyptus gongylocarpa* (marble gum) trees (SASP, SAMU, MAAS).
2. 1%	**Sand dunes** – isolated, generally irregularly shaped dunes with gently inclined flanks and ill-defined crests to 15 m relief but usually less.	Deep red sands (3c).	Spinifex hummock grasslands with well developed shrub strata (SDSH) and occasionally dominated by *E. gongylocarpa.*
3. 18%	**Loamy plains** – areas continuous with unit 1, usually on the margins of the system, receiving diffuse sheet run-on from adjacent land systems.	Deep red clayey sands and red earths, locally over hardpan (3a, 6a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands grading into spinifex hummock grasslands as surface drainage influences dissipate (MUBW, PLMS, SAMU).
4. <1 %	**Drainage foci** – very occasional nearly circular swamps and claypans to 300 m wide.	Deep clays (9b).	Very variable; bare claypans or moderately close (20-30% PFC) *Melaleuca uncinata* fringing communities or claypan grasslands (ACGU).

VIOLET LAND SYSTEM (882 km^2, 0.9% of the survey area)

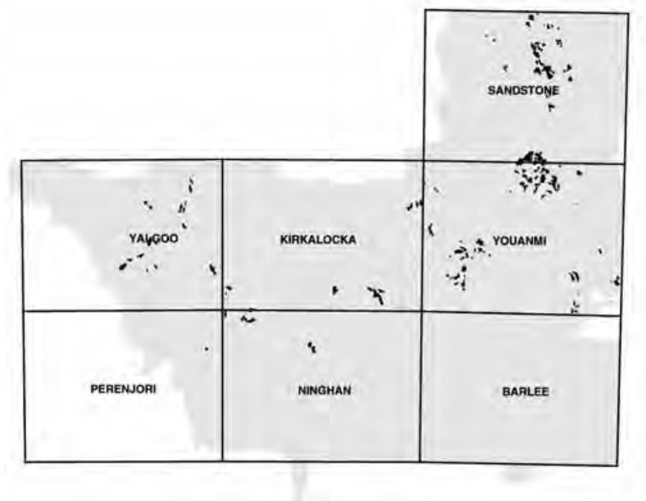
(after Mabbutt *et al.* 1963)

Undulating stony and gravelly plains and low rises supporting mulga shrublands.

Land type: 7

Geology: Archaean greenstone and basalt, Tertiary ferruginous duricrust and Quaternary sand, colluvium, eluvium and minor cemented alluvium.

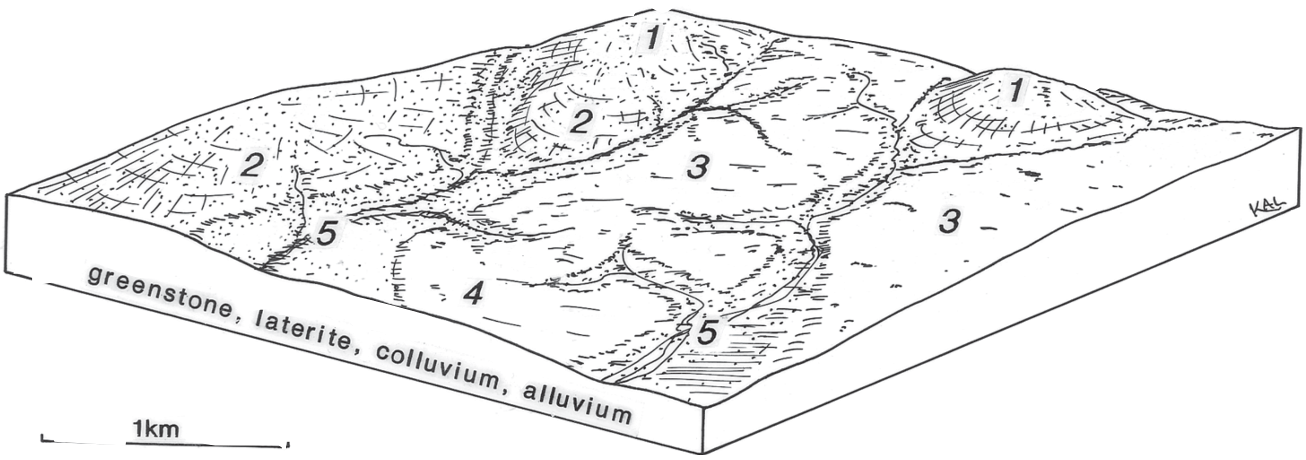
Geomorphology: Erosional surfaces; level to gently inclined plateaux as gravelly sandplains above gently undulating rises of lateritic material and weathered greenstones; level to gently undulating plains with mantles of abundant ironstone and quartz pebbles and cobbles and level to gently inclined lower plains subject to sheet flow and with mantles of fine ironstone pebbles; sparse, sluggish, occasionally channelled drainage floors; relief mostly <10 m.



Land management: Abundant mantles provide effective protection against soil erosion over most of this land system, except where the soil surface has been disturbed, for example by the construction of tracks and gridlines. In such circumstances the soil becomes moderately susceptible to water erosion. Narrow drainage tracts (unit 5) are mildly susceptible to water erosion.

Traverse condition summary (104 assessments):
Vegetation – good 37%; fair 29%; poor 27%; very poor 7%.
Soil erosion – nil 96%; slight 1%; minor 3%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1	Low rise	15	3
2	Gravelly sandy plain	21	–
3	Stony plain/stony saline plain	41	2
4	Stony or gravelly hardpan plain	31	4
5	Narrow drainage tract	13	–
	Other	2	–
	Total	123 *	9

* 19 traverse points not assessed for condition.

Violet land system

Unit area (%)		Landform	Soil	Vegetation
1.	15%	**Low rises** – rounded low rises (<10 m relief), often with ferruginous duricrust and mantles of abundant ironstone pebbles and cobbles.	Shallow red earths and stony soils on gravel (5c, 1).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrublands (SIMS).
2.	20%	**Gravelly sandy plains** – level to very gently inclined plains with mantles of abundant fine ironstone gravel.	Shallow red clayey sands with ferruginous gravel or shallow hardpan loams (2b, 5d).	Very scattered to scattered (2.5-20% PFC) *A. aneura* and *A. ramulosa* (bowgada) tall shrublands with sparse wanderrie grasses (LACS, MUBW, PLMS).
3.	35%	**Stony plains/saline stony plains** – gently undulating to level plains below units 1 and 2, with mantles of many to abundant ironstone and quartz pebbles and cobbles.	Shallow red earths on greenstone (5c).	Very scattered to scattered (2.5-20% PFC) *A. aneura* tall shrublands or *Ptilotus* spp. low shrublands (SIMS, SAES). Also very scattered to scattered acacia tall shrublands with halophytic low shrubs (HMCS, SBMS).
4.	20%	**Stony or gravelly hardpan plains** – level to very gently inclined plains subject to sheet flow, mantles of ironstone and quartz gravel and pebbles.	Stony soils or shallow red earths over ferruginous gravel or hardpan (1, 5c).	Very scattered to moderately close (2.5-30% PFC) *A. aneura* and *A. ramulosa* tall shrublands (LHMS, HPMS); occasionally close *A. aneura* tall shrublands in groves (GRMU).
5.	10%	**Narrow drainage tracts** – narrow drainage floors (<350 m wide), locally incised in upper parts of the system.	Deep red earths (6a).	Moderately close to close (20-50% PFC) *A. aneura* tall shrublands or woodlands with very sparse understoreys (DRAS).

WAGUIN LAND SYSTEM (1,249 km², 1.3% of the survey area)

(after Mabbutt *et al.* 1963)

Low breakaways with short stony and sandy plains, supporting acacia shrublands and minor halophytic shrublands.

Land type: 4

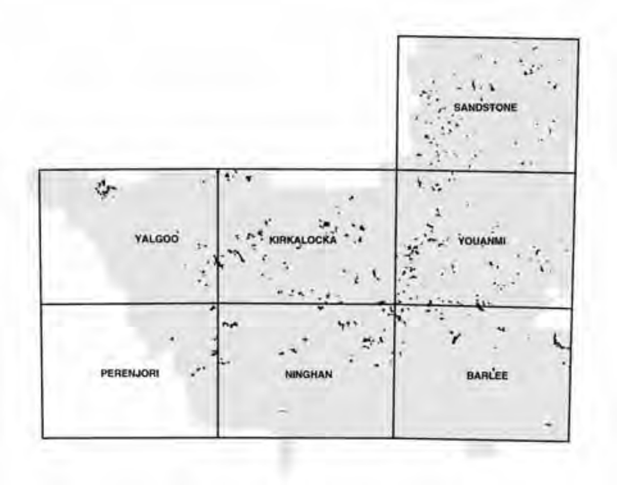
Geology: Deeply weathered Archaean granite and Quaternary colluvium and alluvium.

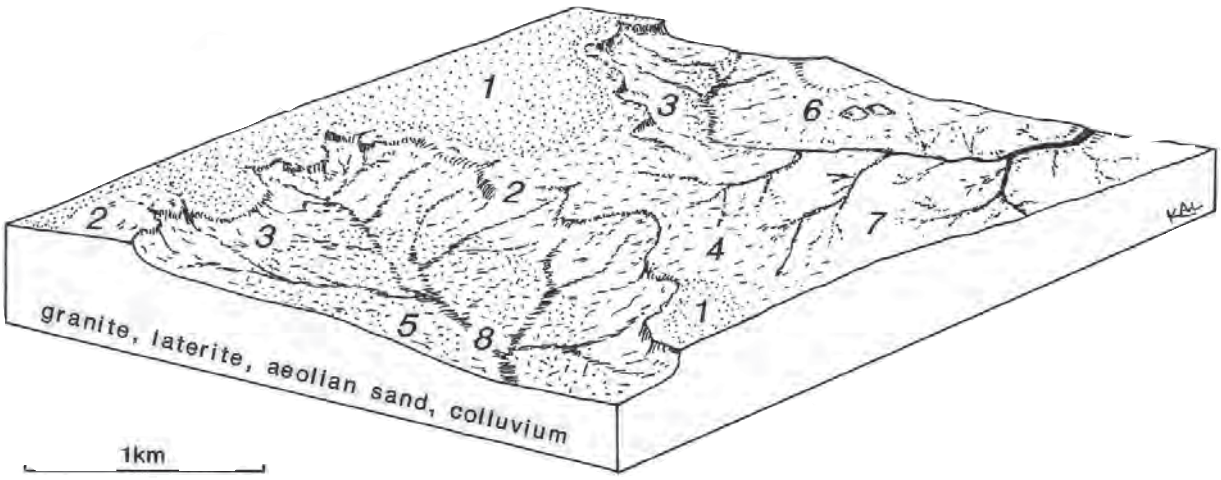
Geomorphology: Erosional surfaces; very low breakaways (relief usually <6 m) with short footslopes shedding water to stony plains and minor alluvial plains downslope. Minor patches of sandplain. This system usually occurs within large areas of sandplain, often occurring in parallel series in the north-east of the survey area.

Land management: Breakaway footslopes (unit 3) have fragile soils which are particularly susceptible to soil erosion if disturbed. Some of the vegetation types on this land system are preferentially grazed by introduced and native animals, especially as the system often occurs within large areas of spinifex vegetation which is unattractive to stock.

Traverse condition summary (123 assessments):
Vegetation – good 60%; fair 26%; poor 11%; very poor 3%.
Soil erosion – nil 99%; moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Sandplain	10	1
2	Breakaway	17	6
3	Lower footslope	4	1
4	Stony plain	15	2
5	Saline stony plain	5	–
6	Gritty surfaced plain	16	1
7	Loamy sand/hardpan plain	43	–
8	Drainage floor	13	3
	Other	6	1
	Total	129 *	15

* 6 traverse points not assessed for condition.

Waguin land system

Unit	area (%)	Landform	Soil	Vegetation
1.	10%	**Sandplains** – very gently inclined remnant tracts of sand to 2 km in extent and elevated several metres above surrounding plains.	Deep red clayey sands (3a).	Moderately close (20-30% PFC) acacia tall shrublands with a wanderrie grass layer (SWGS). Grasses include *Monachather paradoxa* (broad-leaved wanderrie) and *Eragrostis eriopoda* (woolly butt)
2.	15%	**Breakaways** – low breakaways and plateaux on ferricrete, silcrete and granite, mostly up to 6 m relief; very gently inclined stripped surfaces with common weathered granite outcrop and many quartz, ironstone or silcrete cobbles and pebbles; moderately inclined to steep breakaway faces and short pallid zone scree slopes.	Pockets of stony soils on plateaux (1); shallow duplex on granite on footslopes (7a).	Scattered (10-20% PFC) low shrubland with *Acacia quadrimarginea* (granite wattle) mid to tall shrubs or scattered to moderately close (10-30% PFC) acacia tall shrubland (BRXS) on stripped surfaces and plateaux; very scattered (2.5-10% PFC) low shrublands on upper footslopes, with *Ptilotus obovatus* (cotton bush) and *Sida calyxhymenia* (tall sida); occasionally with moderately close (20-30% PFC) *Melaleuca uncinata* (broombush) tall shrubland near scarp faces (UFTH).
3.	10%	**Lower footslopes** – short very gently inclined slopes extending 100 to 500 m downslope from breakaways.	Shallow duplex on granite or hardpan (7a, 7c).	Scattered (10-20% PFC) halophytic low shrubland (BCLS), may be dominated by *Frankenia* spp.
4.	10%	**Stony plains** – gently undulating plains with variable mantles and minor to common outcrop of granite and quartz.	Very shallow coarse red clayey sands on granite (2a).	Scattered (10-20% PFC) acacia-eremophila tall shrublands (SAES).
5.	5%	**Saline stony plains** – level to gently undulating plains with quartz pebble mantles.	Shallow duplex with a stony mantle on granite (7a).	Very scattered to scattered (2.5-20% PFC) *Maireana* spp. (bluebush) low shrublands (SBMS).
6.	15%	**Gritty surfaced plains** – level to gently undulating plains with grit mantles and minor outcrop of granite.	Shallow coarse red clayey sands on granite (2a).	Very scattered (2.5-10% PFC) acacia shrublands, mostly *A. quadrimarginea* (SGRS).
7.	25%	**Loamy plains/hardpan plains** – level to gently undulating plains downslope from other units, receiving diffuse run-on.	Deep red clayey sands or deep red earths on hardpan (3a, 6a).	Scattered (10-20% PFC) *Acacia aneura* (mulga) and other acacia tall shrublands with patchy wanderrie grasses (PLMS, MUBW, HPMS).
8.	10%	**Drainage floors** – narrow drainage floors and alluvial plains with shallow channels or receiving sheet flow from units 2, 3 and 4, may be saline.	Shallow red duplex on hardpan or granite (7c, 7a).	Moderately close (20-30% PFC) acacia tall shrublands including *Acacia tetragonophylla* (curara) and *A. ramulosa* (bowgada) (DRAS). Scattered (10-20% PFC) halophytic low shrublands (SBMS, PXHS, SSAS) on saline soils.

WATSON LAND SYSTEM (155 km², 0.2% of the survey area)

Hills, rises and gravelly plains on sedimentary rocks supporting bowgada shrublands with non-halophytic undershrubs.

Land type: 1

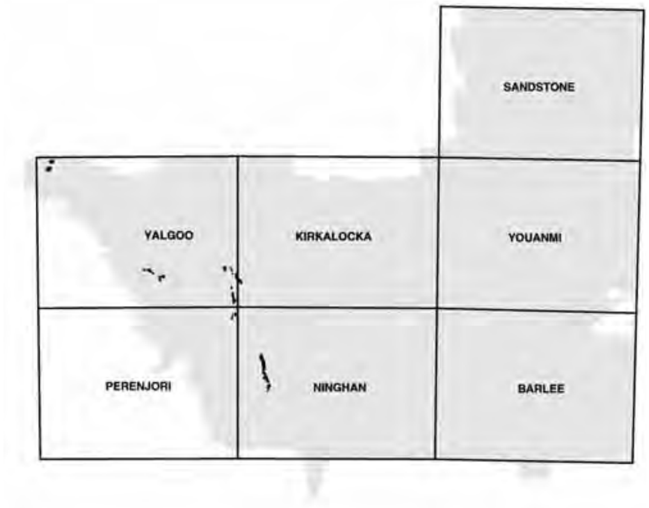
Geology: Archaean fine grained sedimentary rocks, schist and some felsic volcanics, Quaternary colluvium and lateritic gravel.

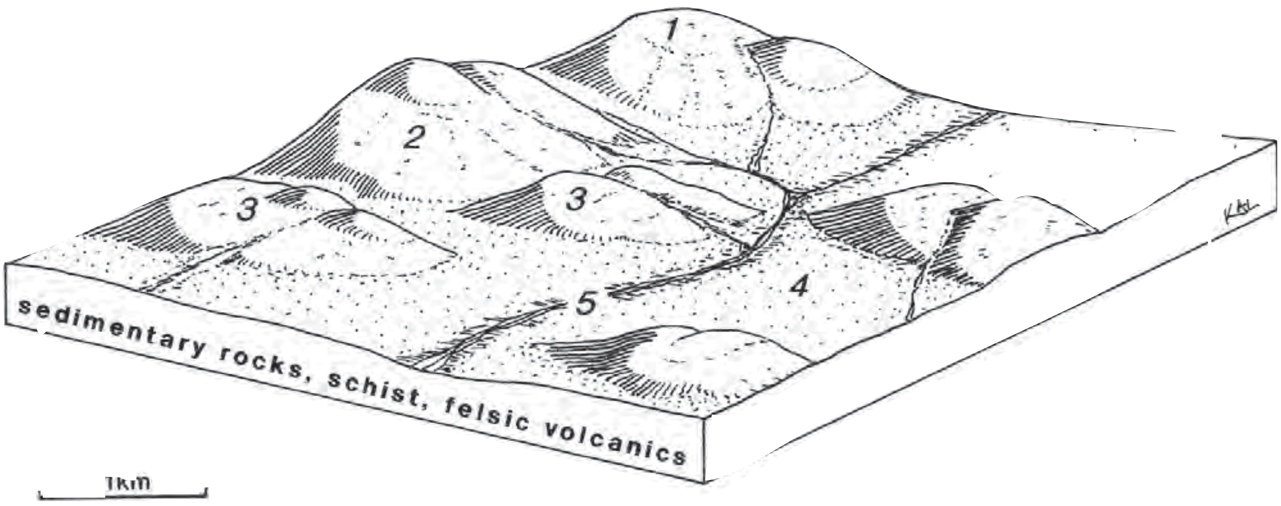
Geomorphology: Erosional surfaces; hills and stony upper slopes, gently undulating rises and gently inclined lower colluvial slopes grading downslope to almost level, gravelly plains; narrow drainage tracts; relief occasionally to 140 m but usually much less.

Land management: Stone and gravel surface mantles provide effective protection against erosion; disturbance or removal of mantle may initiate erosion.

Traverse condition summary (12 assessments):
Vegetation – good 25%; fair 42%; poor 17%; very poor 16%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Hillcrest	–	–
2	Hillslope	1	1
3	Low rise	–	1
4	Gravelly plain/stony plain	9	2
5	Drainage floor	–	–
	Other	2	–
	Total	12	4

Watson land system

Unit	area (%)	Landform	Soil	Vegetation
1.	20%	**Hillcrests** – hill summits to 140 m above adjacent units, and short upper slopes; abundant stony mantles.	Much rock outcrop and stony mantle, pockets of very shallow stony soils (1).	Moderately close (20-30% PFC) tall shrublands of *Acacia ramulosa* (bowgada) and other acacias (GHAS, SIAS).
2.	40%	**Hillslopes** – gently inclined lower slopes, mantles of abundant angular ironstone and sedimentary rocks.	Very shallow red earths on parent rock or gravel (5c).	Moderately close (20-30% PFC) tall shrublands of *A. ramulosa* with *Eremophila* and *Thryptomene* spp. low shrubs (SIAS).
3.	15%	**Low rises** – gently undulating rises with mantles of abundant gravel and cobbles, relief up to 20 m above surrounding units.	Very shallow coarse red clayey sands on granite (2a).	Moderately close (20-30% PFC) tall shrublands of *A. ramulosa* (GHAS, SIAS).
4.	20%	**Gravelly plains/stony plains** – level to very gently inclined plains with mantles of common to abundant ironstone, quartz and sedimentary gravels.	Shallow hardpan loams or red earths over hardpan or gravel (5d, 5c). Some deep red clayey sands on gravel (3a).	Moderately close to close (20-50% PFC) tall shrublands of *A. ramulosa* (HCAS).
5.	5%	**Drainage floors** – sparse narrow (mostly <100 m) drainage zones with shallow channels in higher sectors.	Juvenile soils of variable depth or shallow red earths (12, 5c).	Moderately close to close (20-50% PFC) tall shrublands of *A. ramulosa* and other acacias (HCAS).

WILSON LAND SYSTEM (37 km^2, 0.04% of the survey area)

(after Pringle *et al.* 1994)

Large creeks with extensive distributary fans supporting mulga and halophytic shrublands.

Land type: 17

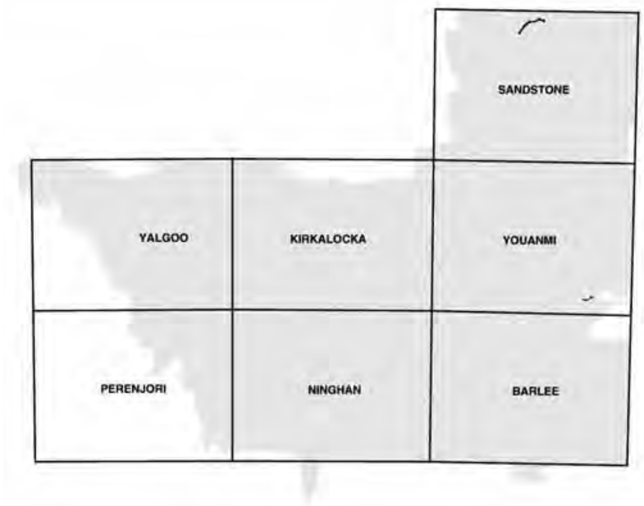
Geology: Quaternary alluvium.

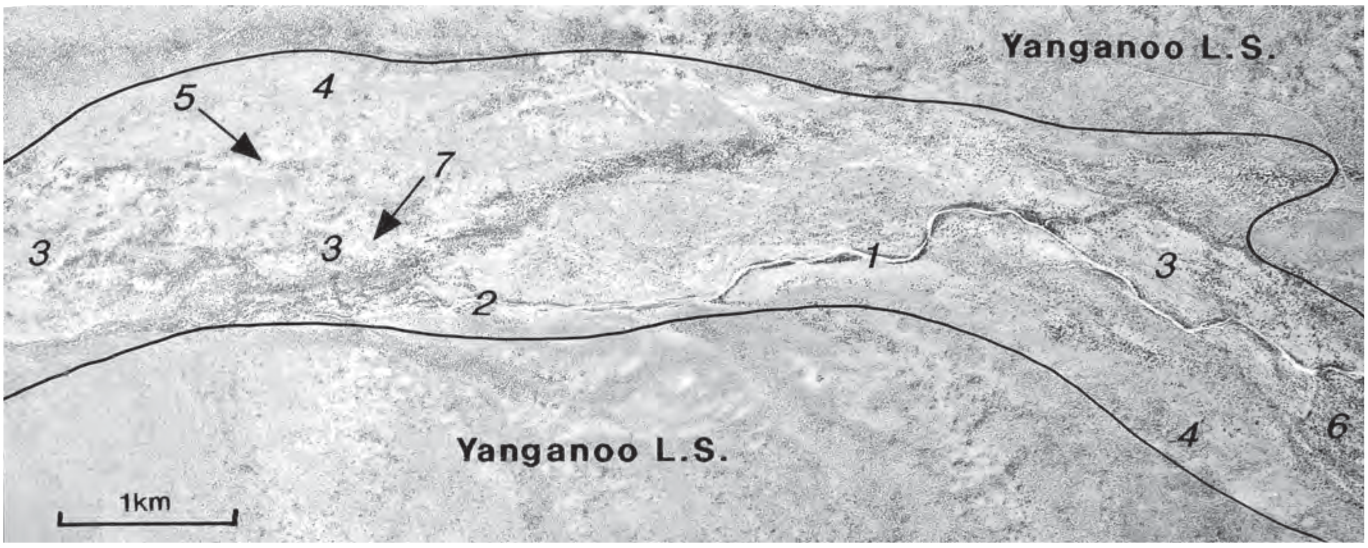
Geomorphology: Depositional surfaces; narrow upper alluvial plains with incised channels and associated overbank deposits, broad lower distributary fans, drainage foci in the lower areas and narrow marginal plains subject to diffuse sheet flow.

Land management: This land system is second only to Monitor in terms of the proportion of its area that is now severely degraded and eroded. The drainage tracts (unit 2) and alluvial fans (unit 3) are the most extensively eroded. The vegetation of this system is highly preferred for grazing by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure.

Traverse condition summary (24 assessments):
Vegetation – good 21%; fair 37%; poor 17%; very poor 25%.
Soil erosion – nil 71%; slight 4%; minor 13%; moderate 8%; severe 0%; extreme 4%.

Area mapped as sde: 6 km^2 (16.3% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Channel	–	3
2	Drainage tract	16	–
3	Alluvial fan	7	1
4	Hardpan plain	9	–
5	Sandy bank	–	–
6	Calcrete plain	1	1
7	Drainage focus	1	–
	Other	2	–
	Total	26 *	5

* 2 traverse points not assessed for condition.

Wilson land system

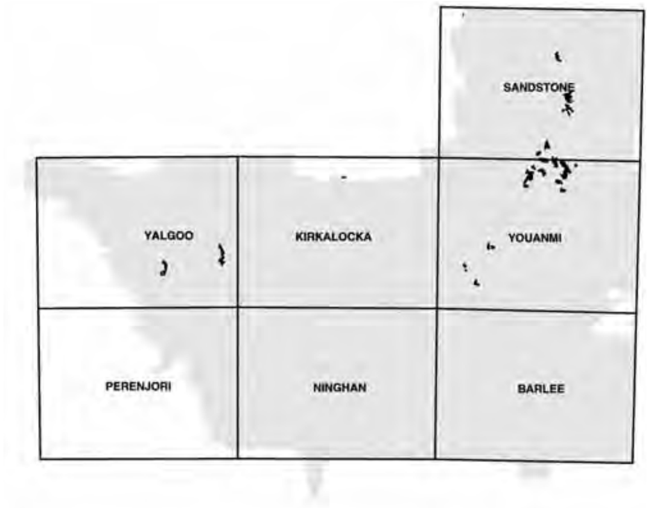
Unit	area (%)	Landform	Soil	Vegetation
1.	2%	**Channels** – incised drainage lines to 50 m wide and 4 m deep, often with exposed hardpan.	Juvenile alluvial deposits and coarse overbank deposits (12).	Fringing moderately close to close (20-50% PFC) acacia tall shrublands including *A. acuminata* subsp. *burkittii* (fine-leaf jam) and *A. tetragonophylla* (curara). Rushes such as *Cyperus* spp. may be common on banks (CBKW).
2.	30%	**Drainage tracts** – alluvial plains (<800 m wide), subject to overbank flooding from unit 1.	Shallow duplex on hardpan (7c), and juvenile deposits adjacent to channels (12).	Scattered to moderately (10-30% PFC) close *Acacia aneura* (mulga) tall shrublands often with halophytic understorey (HMCS, DRAS).
3.	25%	**Alluvial fans** – level to very gently inclined plains receiving distributary flow from units 1 and 2.	Shallow saline duplex, of variable depth on hardpan (7c).	Scattered (10-20% PFC) halophytic low shrublands occasionally with *Cratystylis subspinescens* (sage) or *Atriplex bunburyana* (silver saltbush) dominant (PXHS, SSAS). Also acacia tall shrublands with halophytic low shrubs (HMCS).
4.	38%	**Hardpan plains** – level plains with mantles of abundant fine quartz gravel, subject to sheet flow.	Shallow red clayey sands or shallow red earths, on hardpan (2d, 5c).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrublands (HPMS).
5.	3%	**Sandy banks** – very low banks (<1 m relief), occurring occasionally on units 3 and 4.	Deep red clayey sands on hardpan (3a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with wanderrie grasses (WABS), may support halophytic low shrubs (SBLS) near salt lakes.
6.	2%	**Calcrete plains** – level plains based on calcrete.	Shallow calcareous loams on calcrete (5a).	Moderately close (20-30% PFC) *A. acuminata* subsp. *burkittii* tall shrubland with calciphytic shrubs (JAMS).
7.	<1%	**Drainage foci** – irregular sump areas to 100 m wide, in unit 3.	Deep clays or deep red earths (9b, 6a).	Moderately close to close (20-50% PFC) *A. aneura* tall shrublands (DRAS) occasionally with claypan grasses e.g. *Eriachne flaccida* (ACGU).

WILUNA LAND SYSTEM (386 km², 0.4% of the survey area)

(after Mabbutt *et al.* 1963)

Greenstone hills, breakaways and lower plains supporting mulga shrublands occasionally with understoreys of halophytic shrubs.

Land type: 1



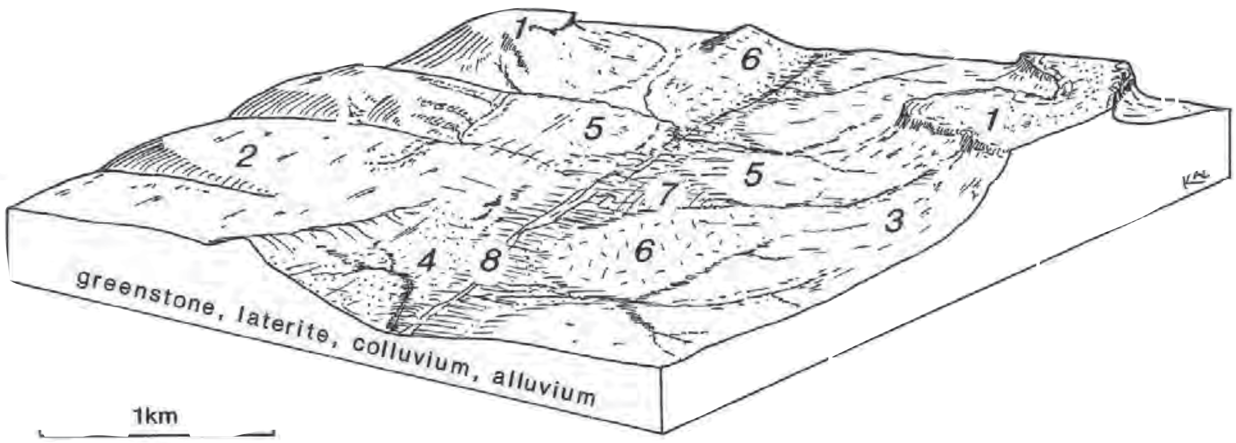
Geology: Archaean amphibolite, basalt and schistose rocks with Tertiary laterite capping; Quaternary colluvium and alluvium.

Geomorphology: Erosional surfaces; residual lateritised plateaux with stripped surfaces and eroding breakaways, generally 10-30 m high above steep footslopes; rounded hills of basalt or occasional linear strike ridges; rounded lower footslopes dissected by narrow valleys and alluvial fans; broad stony plains, some saline, mantled by ironstone, quartz and greenstone fragments; drainage floors with more or less groved vegetation and minor channels; overall relief mainly 20-40 m, locally higher.

Land management: Due to its stony nature much of this system is not generally susceptible to erosion; however disturbance of the stony mantle, especially on sloping areas can result in erosion. Some vegetation types on this system are preferred by grazing animals and are susceptible to overgrazing and consequent degradation; units 6, 7 & 8 are mildly to moderately susceptible to accelerated erosion when degraded.

Traverse condition summary (48 assessments):
Vegetation – good 27%; fair 27%; poor 23%; very poor 23%.
Soil erosion – nil 90%; minor 6%; moderate 2%; extreme 2%.

Area mapped as sde: 1.9 km² (0.5% of land system's area).



No.	Unit name	Traverse recordings	Inventory sites
1	Plateau and breakaway	–	1
2	Low hill/strike ridge/low rise	9	5
3	Stony footslope	3	4
4	Gravelly plain	4	1
5	Stony plain/interfluve	15	1
6	Saline stony plain	12	4
7	Alluvial fan/plain	6	–
8	Drainage floor	4	2
	Other	4	–
	Total	57 *	18

* 9 traverse points not assessed for condition.

Wiluna land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Plateaux and breakaways** – plateaux with indurated surfaces over weathered rock and breakaway scarp to 30 m; plateaux slopes and crests with mantles of abundant ironstone pebbles and cobbles.	Isolated pockets of stony soils (1).	Very scattered to scattered (2.5-20% PFC) mixed height acacia shrublands with *Eremophila* spp., *Thryptomene decussata* and other stunted low shrubs (BRXS).
2.	22%	**Low hills, spurs, strike ridges and rises** - rounded laterite or greenstone hills and spurs to 25 m high with variable slopes (to 15% or more), occasional narrow strike ridges of jaspilite or basalt; mantles of abundant ironstone and quartz pebbles and cobbles.	Shallow stony red earths or stony soils (5b, 1).	Very scattered to moderately close (2.5-30% PFC) *Acacia aneura* (mulga) tall shrublands, prominent understorey species are *Eremophila* and *Ptilotus* spp. (GHAS, SIAS).
3.	15%	**Stony footslopes** – broad concave footslopes with upper slopes to 10% decreasing to 1% downslope, abundant mantles of ironstone, quartz or basalt pebbles with occasional greenstone or quartz outcrops.	Shallow duplex (7b). Shallow red earths and shallow clays on basalt or greenstone (5c, 9a).	Very scattered to moderately close (2.5-30% PFC) tall shrublands of *A. aneura* and other acacias with non-halophytic and halophytic low shrubs (SIAS, HMCS), also low shrublands of *Maireana* (bluebush) and *Halosarcia* spp. (samphire) (BCLS, SAMP).
4.	5%	**Gravelly plains** – gently undulating plains and slopes lower than units 1 and 2, mantles of lateritic gravels and pebbles.	Shallow red earth on gravel or shallow red clayey sands with ferruginous gravel (5c, 2b).	Scattered (10-20% PFC) *A. aneura, A. ramulosa* (bowgada) tall shrublands (LACS).
5.	25%	**Stony plains and interfluves** – level to gently undulating lower plains and interfluves with mantles of ironstone and quartz pebbles and cobbles.	Shallow hardpan loams, shallow red earths or shallow duplex over hardpan or metamorphic parent material (5d, 5c, 7c, 7b).	Scattered (10-20% PFC) A. aneura and other acacia tall shrublands, *Eremophila* spp. low shrubs (SAES, SIAS).
6.	15%	**Saline stony plains** – level to gently undulating lower plains adjacent to units 7 and 8, mantles of ironstone and quartz pebbles and cobbles.	Shallow duplex and clays over hardpan or metamorphic parent material (7c, 7b, 9a).	Very scattered to scattered (2.5-20% PFC) acacia tall shrublands with halophytic understoreys (HMCS) or low shrublands of *Maireana* spp. (SBMS).
7.	5%	**Alluvial fans and plains** – very gently inclined saline alluvial fans with scalded sandy surfaces, variable density mantles of quartz and other pebbles.	Deep duplex soils (8).	Very scattered to scattered (2.5-20% PFC) low or mixed height *Acacia* and *Maireana* spp. shrublands (MHHS, PSAS).
8.	8%	**Drainage floors** – narrow drainage floors grading into tracts to 300 m wide with shallow channels incised in sandy alluvium; occasional contour aligned grove formations occur downslope.	Shallow duplex on greenstone and variable depth juvenile soils (7b, 12).	Moderately close to close (20-50% PFC) woodlands or tall shrublands of *A. aneura* and other acacias sometimes with halophytic understoreys (DRAS, DMCS).

WINDARRA LAND SYSTEM (370 km^2, 0.4% of the survey area)

(after Pringle *et al.* 1994)

Stony plains with quartz mantles supporting acacia-eremophila shrublands.

Land type: 9

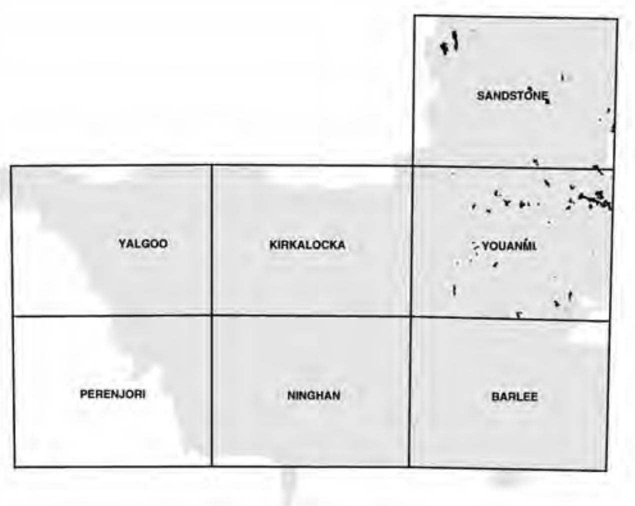
Geology: Archaean granite and Quaternary colluvium.

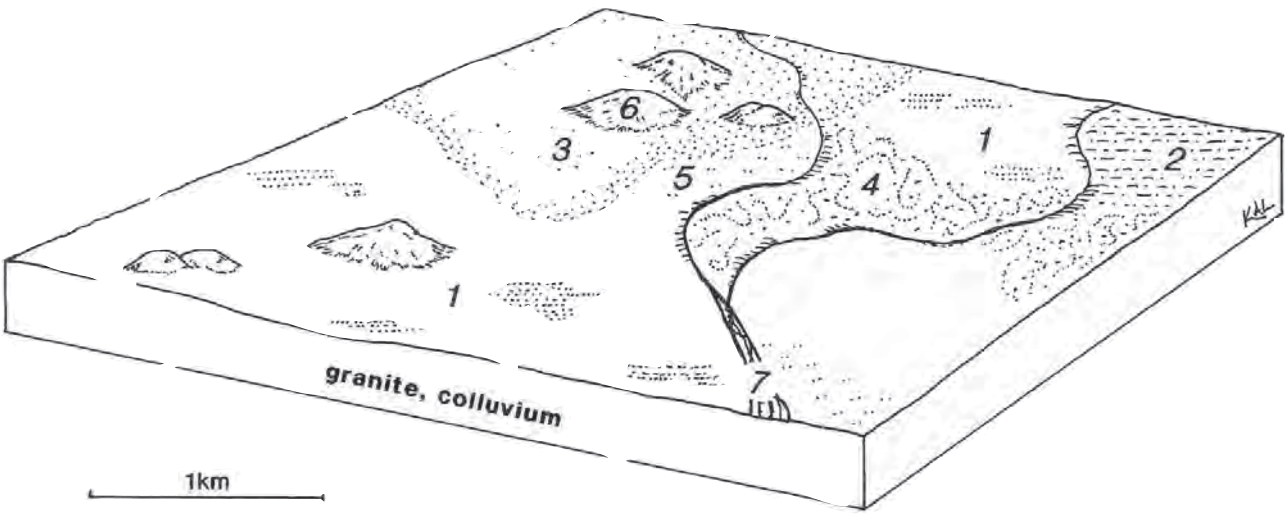
Geomorphology: Erosional surfaces; level to gently undulating plains and low rises with quartz pebble mantles; sparse, narrow drainage zones, minor tors, domes and ridges with fringing gritty surfaced plains and lower plains subject to sheet flow.

Land management: Generally stony mantles provide effective protection against erosion.

Traverse condition summary (56 assessments):
Vegetation – good 22%; fair 23%; poor 41%; very poor 14%.
Soil erosion – nil 91%; slight 4%; moderate 2%; extreme 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Stony plain	17	2
2	Saline stony plain	3	–
3	Gritty-surfaced plain	14	1
4	Hardpan plain	11	–
5	Loamy plain	4	–
6	Low rise	–	–
7	Drainage floor	6	1
	Other	4	–
	Total	59 *	4

* 3 traverse points not assessed for condition.

Windarra land system

Unit area (%)	Landform	Soil	Vegetation
1. 50%	**Stony plains** – level to gently undulating plains with mantles of many to abundant quartz and ferruginous large pebbles and minor granite outcrop.	Shallow red earths or shallow coarse red clayey sands on granite (5c, 2a).	Scattered (10-20% PFC) *Acacia aneura* (mulga) – eremophila shrublands (SAES). Eremophila species include *E. fraseri* (turpentine bush), *E. macmillaniana* (grey turpentine bush), *E. latrobei* (warty fuchsia bush), *E. compacta* (felty fuchsia bush) and *E. exilifolia* (little turpentine poverty bush).
2. 5%	**Saline stony plains** – level to gently undulating plains with a quartz gravel mantle.	Shallow duplex on granite (7a).	Scattered (10-20% PFC) *Maireana* spp. (bluebush) low halophytic shrublands (SBMS).
3. 15%	**Gritty-surfaced plains** – level to gently undulating plains and stripped surfaces with fine quartz gravel and coarse sand mantles and granite outcrop.	Very shallow coarse red clayey sands on granite (2a).	Very scattered to scattered (2.5-20% PFC) *Acacia quadrimarginea* (granite wattle) shrublands (SGRS).
4. 15%	**Hardpan plains** – nearly level plains locally with a quartz pebble mantle, subject to sheet flow.	Shallow red earths, or red clayey sands, on hardpan (5c, 2d).	Scattered (10-20% PFC) *Acacia aneura* tall shrublands (HPMS).
5. 5%	**Loamy plains** – level plains downslope from units 1, 2 and 3.	Deep red earths (6a).	Scattered (10-20% PFC) *A. aneura* tall shrublands with a wanderrie grass component (MUWA, PLMS).
6. 2%	**Low rises** – granite tors, domes and ridges (quartz dykes) with much rock outcrop, relief mostly <8 m.	Shallow coarse red clayey sands (2a).	Not vegetated or very scattered (2.5-10% PFC) *A. quadrimarginea* tall shrublands (GRHS).
7. 8%	**Drainage floors** – drainage zones, receiving run-on from granite tors and low rises, occasionally channelled.	Shallow red earths or clays on granite (5c, 9a) and juvenile alluvial soils (12).	Moderately close (20-30% PFC) *A. aneura* tall shrublands sometimes with a perennial grass component (DRAS).

WOODLINE LAND SYSTEM (5,856 km^2, 6.2% of the survey area)

(after Curry *et al.* 1994)

Hardpan wash plains supporting acacia shrublands and woodlands.

Land type: 13

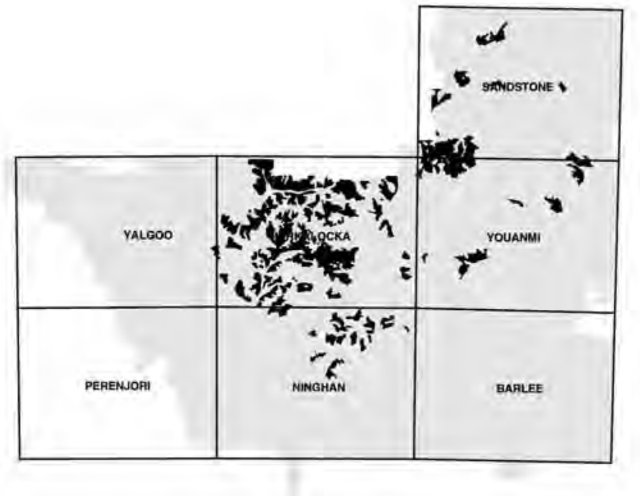
Geology: Quaternary cemented alluvium and minor aeolian sand.

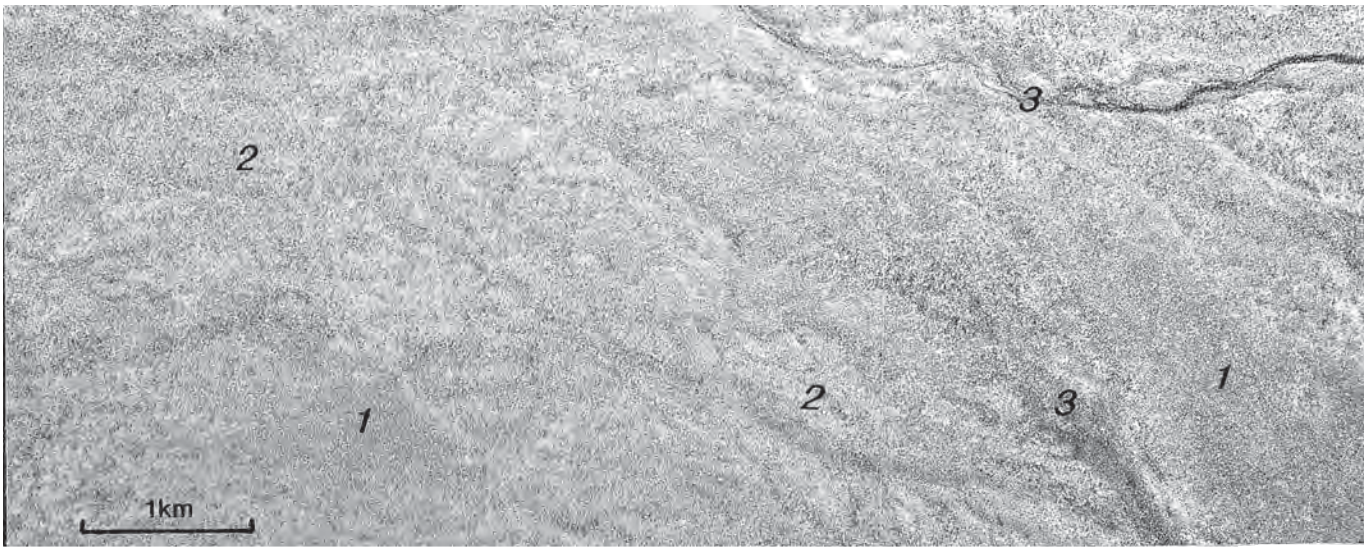
Geomorphology: Depositional surfaces; broad, nearly level plains receiving sheet run-on from adjacent higher systems, more concentrated flow zones (rarely with channels) and minor tracts of sandplain.

Land management: The mulga woodlands on this system were formerly subject to extensive timber cutting for the mining industry but have now largely recovered. The system is generally not prone to accelerated soil erosion. However, impedance to overland flow (e.g. by roads and tracks diverting run-off) can cause water starvation effects on vegetation downslope.

Traverse condition summary (695 assessments):
Vegetation – good 27%; fair 41%; poor 27%; very poor 5%.
Soil erosion – nil 99%; slight 1%.

Area mapped as sde: 0.4 km^2 (0.01% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Sand sheet	20	2
2	Hardpan plain/loamy plain	649	11
3	Drainage tract	48	7
	Other	16	–
	Total	733 *	20

* 38 traverse points not assessed for condition.

Woodline land system

Unit	area (%)	Landform	Soil	Vegetation
1.	5%	**Sand sheets** – level sandy tracts, to 2 km in extent and slightly elevated, above other units.	Deep red clayey sands, sandy red earths or red earths (3a, 4, 6a).	Scattered to moderately close (10-30% PFC) *Acacia ramulosa* (bowgada) tall shrublands with a *Monachather paradoxa* (broad-leaved wanderrie) grass layer (SWGS).
2.	85%	**Hardpan plains/loamy plains** – nearly level, loamy surfaced plains (usually 5-10 km wide), receiving sheet flow from granite uplands; indistinct arcuate, contour-aligned patterns of grove and intergrove.	Deep red earths on hardpan (6a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands, dominated by *Acacia aneura* (mulga), *A. ramulosa* or *A. grasbyi* (miniritchie) (HPMS, HCAS), often with an *A. aneura* tree layer (MUBW, PLMS). Occasionally closed (>50% PFC) acacia woodlands (GRMU).
3.	10%	**Drainage tracts** – Mostly unincised drainage tracts generally 50-200 m wide, carrying more concentrated sheet flow; occasionally incised channels to 80 m wide and 2 m deep.	Deep red earths on hardpan or occasional shallow hardpan loams (6a, 5d).	Moderately close to close (20-50% PFC) *A. aneura* or *A. ramulosa* tall shrublands or *A. aneura* woodlands (DRAS).

YALLUWIN LAND SYSTEM (247 km^2, 0.3% of the survey area)

Hardpan plains and drainage tracts carrying concentrated flow supporting mulga, curara and other acacias.

Land type: 13

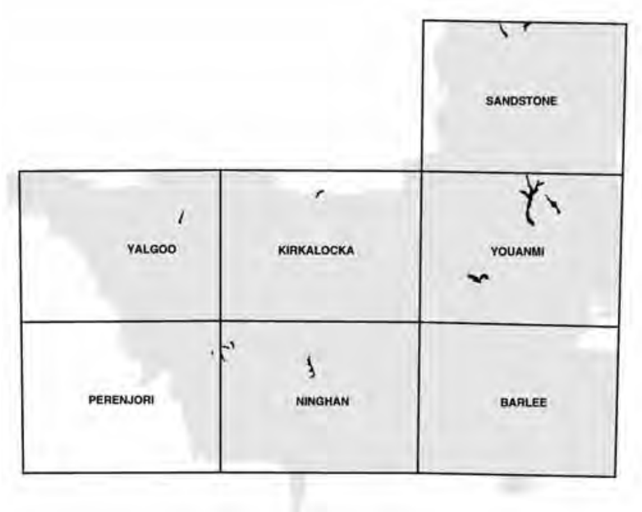
Geology: Quaternary cemented alluvium derived principally from greenstone and laterite.

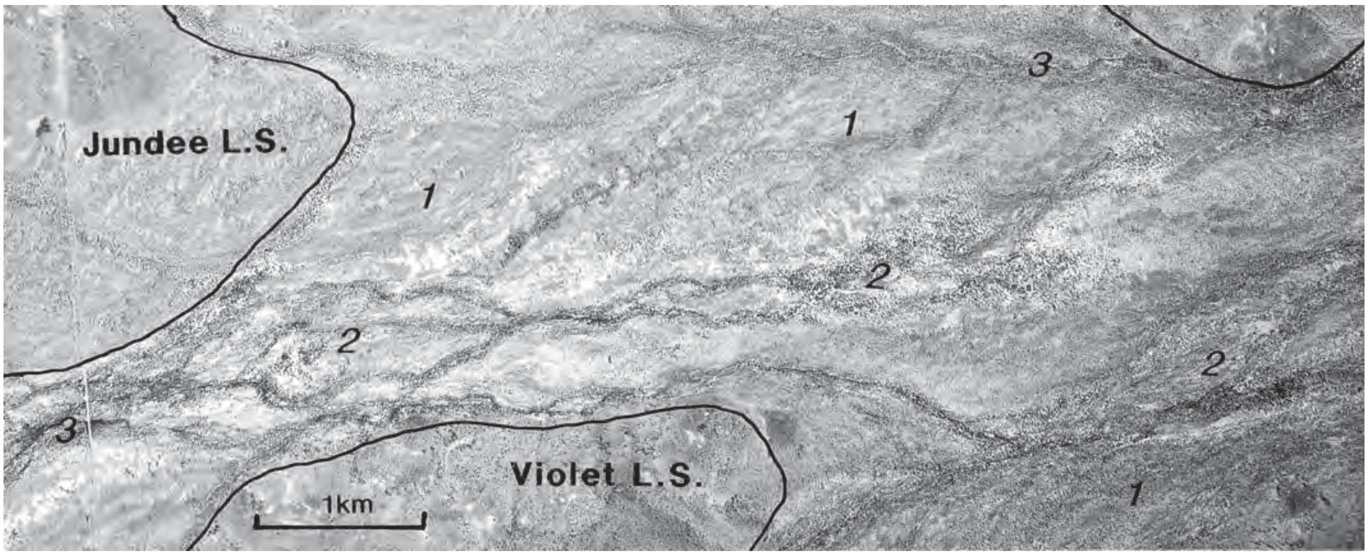
Geomorphology: Depositional surfaces; nearly level plains intermittently subject to sheet flow, prominent central tracts receiving more concentrated through flow and with many small braided channels shallowly incised into hardpan.

Land management: The system is subject to flooding, drainage tracts are moderately susceptible to accelerated water erosion. Impedance to overland flow (e.g. by roads and tracks diverting run-off) can cause water starvation effects on vegetation downslope.

Traverse condition summary (34 assessments):
Vegetation – good 29%; fair 26%; poor 24%; very poor 21%.
Soil erosion – nil 76%; slight 3%; minor 15%; severe 6%.

Area mapped as sde: 8.9 km^2 (3.6% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Hardpan plain/gravelly hardpan plain	24	1
2	Drainage tract	9	5
3	Channel	–	–
	Other	3	–
	Total	36 *	6

* 2 traverse points not assessed for condition.

Yalluwin land system

Unit area (%)	Landform	Soil	Vegetation
1. 50%	**Hardpan plains/gravelly hardpan plains** – nearly level plains on outer margins of system flanking unit 2, variable density surface mantles of ironstone grit and small pebbles, subject to overland sheet flow.	Shallow red earths or hardpan loams (5c, 5d).	Scattered to moderately close (10-30% PFC) *Acacia aneura* (mulga) tall shrublands (HPMS).
2. 45%	**Drainage tracts** – almost level tracts - mostly <500 m wide (occasionally wider), sparse mantles of ironstone and quartz pebbles, subject to concentrated through flow and with numerous small braided channels.	Shallow red earths or moderate to deep clays on hardpan (5c, 9b).	Scattered to close tall (10-50% PFC) shrublands of *A. tetragonophylla* (curara), *A. aneura* and other acacias (HPMS, DRAS).
3. 5%	**Minor channels** – numerous small braided channels to 10 m wide and incised to 1 m; hardpan exposures in channels and bedloads of coarse sand and ironstone grit and pebbles.	Shallow juvenile alluvial soils on channel banks and margins (12), also shallow red earths on hardpan (5c, 5d).	Moderately close to close (20-50% PFC) tall shrublands of *A. tetragonophylla, A. aneura* and other acacias on channel margins (DRAS).

YANGANOO LAND SYSTEM (3,276 km², 3.5% of survey area)

(after Mabbutt *et al.* 1963)

Hardpan plains and sandy tracts with groved mulga shrublands, hard spinifex and wanderrie grasses.

Land type: 14

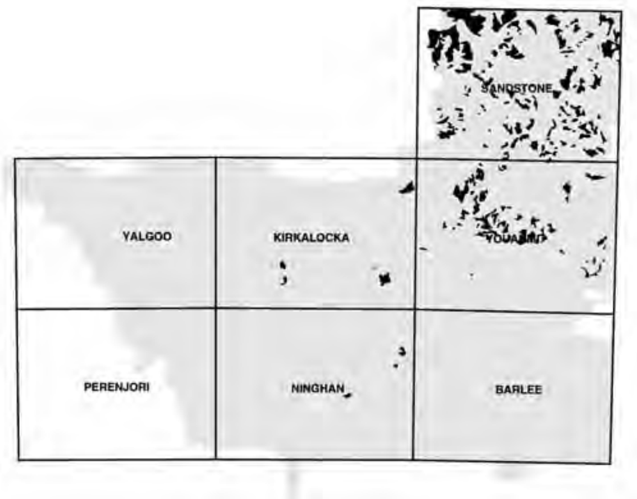
Geology: Quaternary cemented alluvium and sand.

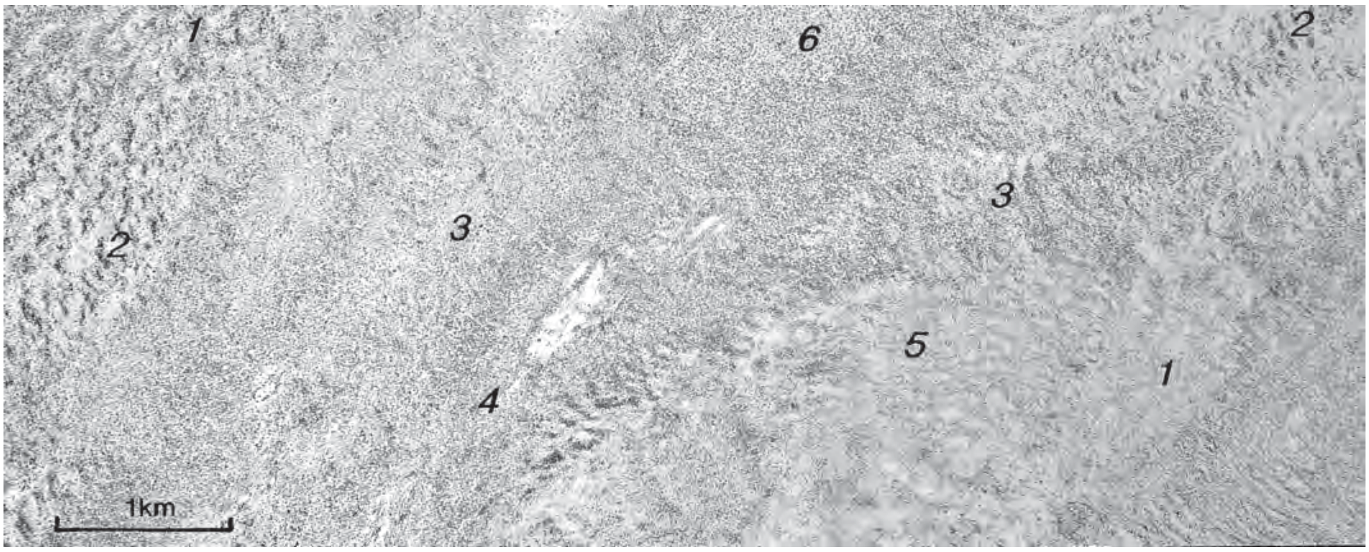
Geomorphology: Depositional surfaces; distributary alluvial plains commonly with central drainage tracts, receiving run-on from adjacent granite uplands; grading downslope and laterally into sandplain.

Land management: This system is generally not susceptible to soil erosion except for drainage tracts (unit 4) receiving concentrated run-on which are moderately susceptible to accelerated erosion if vegetation is degraded. Impedance to sheet flows on hardpan plains (unit 1) can cause water starvation and consequent loss of vigour in vegetation downslope.

Traverse condition summary (479 assessments):
Vegetation – good 29%; fair 28%; poor 37%; very poor 6%.
Soil erosion – nil 94%; slight 1%; minor 4%; moderate 1%.

Area mapped as sde: 3.9 km² (0.1% of land system's area).





No.	Unit name	Traverse recordings	Inventory sites
1	Hardpan plain	205	8
2	Grove	9	3
3	Loamy plain	193	4
4	Drainage tract	48	1
5	Sandy bank	15	–
6	Sand sheet	35	–
	Other	8	–
	Total	513 *	16

* 34 traverse points not assessed for condition.

Yanganoo land system

Unit area (%)	Landform	Soil	Vegetation
1. 40%	**Hardpan plains** – level to gently inclined plains subject to sheet flow.	Shallow hardpan loams and deep red earths on hardpan (5d, 6a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands including *Acacia aneura* (mulga), *A. ramulosa* (bowgada) and *A. tetragonophylla* (curara) (HPMS, HMCS).
2. 2%	**Groves** – arcuate, contour-aligned drainage foci (to 50 m wide and 200 m long) on unit 1, occasionally on unit 3.	Deep red earths (6a).	Close (30-50% PFC) *A. aneura* tall shrublands or woodlands (GRMU).
3. 40%	Loamy plains – level to very gently inclined plains subject to diffuse sheet flow.	Shallow hardpan loams and deep red earths (5d, 6a) or sandy red earths (4).	Scattered to moderately close (10-30% PFC) *A. aneura* tall shrublands with undershrubs such as *Eremophila forrestii* (Wilcox bush) and occasional wanderrie grasses (MUBW, PLMS).
4. 10%	**Drainage tracts** – broad (>500 m) alluvial tracts receiving concentrated run-on from adjacent granite uplands; occasionally with shallow channels incised into hardpan.	Deep red earths (6a).	Moderately close to close (20-50% PFC) *A. aneura* tall shrublands or woodlands with generally sparse understoreys (DRAS).
5. 3%	**Sandy banks** – reticulate sandy banks elevated to 1 m above surrounding plains (units 1 and 3), commonly transverse to slope.	Deep red clayey sands (3a).	Scattered to moderately close (10-30% PFC) acacia tall shrublands with low shrubs such as *E. forrestii* and wanderrie grasses (WABS).
6. 5%	**Sand sheets** – areas transitional to sandplain receiving very diffuse run-on.	Deep red clayey sands and sandy red earths (3a, 4).	Scattered (10-20% PFC) *A. ramulosa, A. aneura* tall shrublands with *Triodia basedowii* (hard spinifex) or wanderrie grass understoreys (SAMU, SWGS).

YARRAMEEDIE LAND SYSTEM (66 km², 0.1% of survey area)

(after Mabbutt *et al.* 1963)

Stony slopes and plains supporting sparse mulga shrublands.

Land type: 9

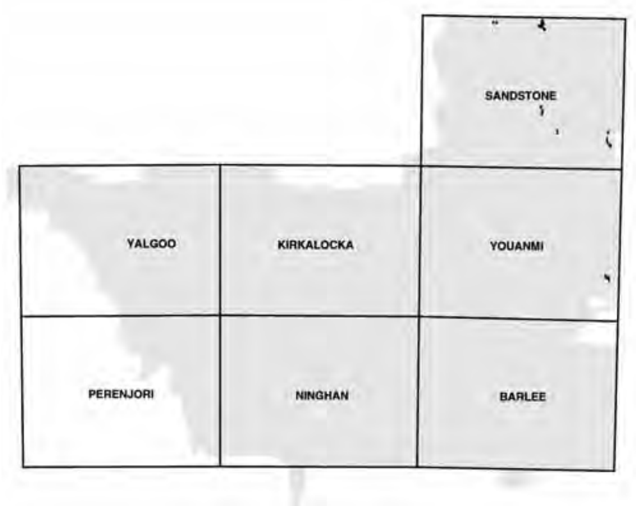
Geology: Archaean metamorphic rocks and Quaternary colluvium.

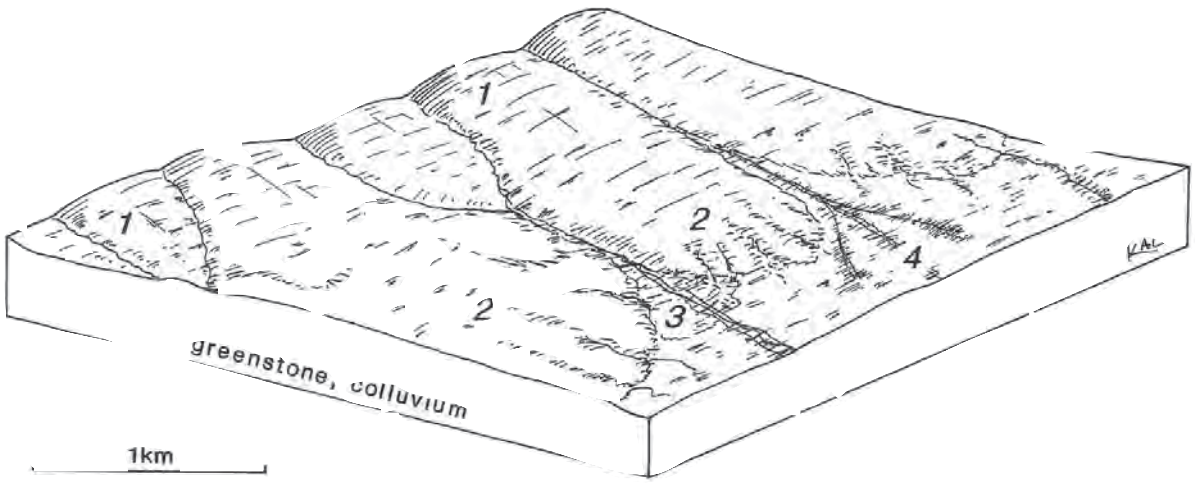
Geomorphology: Erosional surfaces; piedmont slopes and plains; mainly 2-4 km wide, parallel with major ranges, heavy mantles of mixed pebbles and gravels; higher parts consist of spurs and stony interfluvial slopes dissected by often fairly closely spaced, parallel, incised drainage lines leading to narrow drainage floors and spreading into minor alluvial tracts downslope; overall relief mainly 5-20 m.

Land management: Vegetation on the interfluves and plains of this system is naturally sparse but the lower units (3 and 4) are prone to overgrazing and degradation. These units show mild susceptibility to accelerated erosion when vegetation is degraded, elsewhere stony mantles confer resistance to erosion unless disturbed.

Traverse condition summary (28 assessments):
Vegetation – good 25%; fair 39%; poor 18%; very poor 18%.
Soil erosion – nil 93%; minor 4%; moderate 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Footslope and hill spur	1	1
2	Stony plain/stony hardpan plain	18	–
3	Alluvial fan	4	–
4	Drainage floor and creekline	2	1
	Other	3	–
	Total	28	2

Yarrameedie land system

Unit area (%)	Landform	Soil	Vegetation
1. 40%	**Footslopes and hill spurs** – convex slopes and piedmont tracts with slopes to about 4%, occasional low rounded crests to 10 m relief with total relief generally <20 m; abundant mantles of ironstone, greenstone and quartz pebbles and cobbles.	Shallow stony red earths, red clayey sands and occasional duplex soils overlying various metamorphic parent materials (5b, 2d, 7b).	Very scattered to scattered (2.5-20% PFC) mixed acacia shrublands with sparse *Eremophila* and *Ptilotus* spp. low shrubs (SAES).
2. 50%	**Stony plains/stony hardpan plains** – broad, level or gently undulating plains and slightly rounded interfluves to 1 km wide, dissected by drainage lines and associated alluvial fans; abundant mantles of mixed pebbles.	Shallow red clayey sands and shallow red earths over various substrates (2d, 5c).	Very scattered to scattered (2.5-20% PFC) mixed acacia shrublands dominated by stunted *Acacia aneura* (mulga), *Eremophila* and *Ptilotus* spp. (SAES, SIMS, LHMS).
3. 5%	**Alluvial fans** – almost level tracts of shallow sandy and gravelly surfaced alluvium diverging from narrow creeks as slope decreases; mantles of ironstone, quartz or mixed gravel pebbles.	Variable depth red clayey sands over various substrates (2d, 3a).	Very scattered to scattered (2.5-20% PFC) mixed acacia shrublands with occasional groves of denser shrublands (SAES), occasional halophytic low shrubs (HMCS).
4. 5%	**Drainage floors and creeklines** – drainage lines originating as creeklines in neighbouring elevated systems; usually >30 m wide and parallel on upper slopes, broadening to >100 m and coalescing lower in the topography; minor incised channels but mainly becoming disintegrated at alluvial fans or above wash plain systems.	Variable, shallow red clayey sands to deeper sandy red earths (2d, 4).	Scattered to moderately close (10-30% PFC) tall shrublands or woodlands of *A. aneura* (DRAS).

YEWIN LAND SYSTEM (140 km², 0.1% of the survey area)

(after Curry *et al.* 1994)

Saline flood plains supporting halophytic low shrublands with snakewood and spiny snakewood overstoreys.

Land type: 17

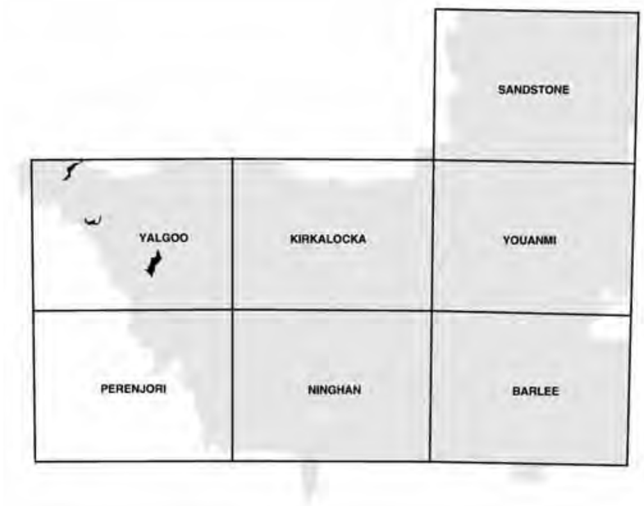
Geology: Quaternary alluvium, aeolian sand and kopi, with minor Tertiary calcrete.

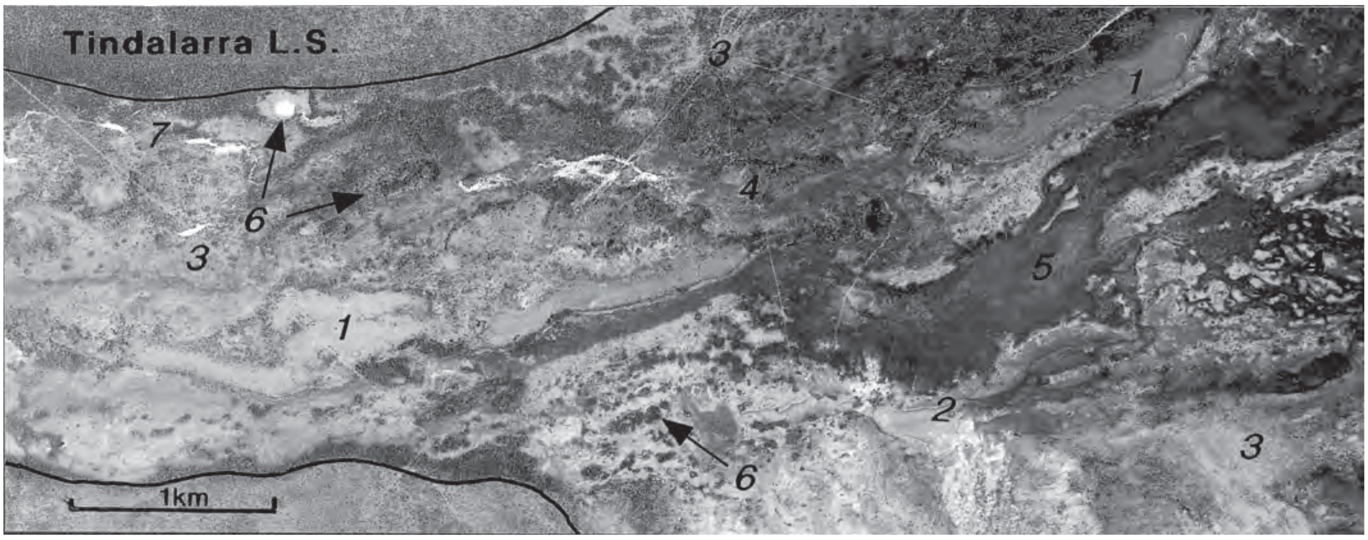
Geomorphology: Depositional surfaces; level riverine plains mainly 3-6 km wide, with minor calcrete rises and isolated low platforms of kopi; major alluvial plains subject to near-annual flooding with many features of through and internal drainage: variable swampy drainage foci and occasional gilgaied floors; many small anastomozing drainage tracts and claypans forming on active flood plains adjacent to major channels. Overall relief mostly <5 m.

Land management: Much of the vegetation on this land system is preferentially grazed by introduced and native animals rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by appropriate management, including control of total grazing pressure. Alluvial plains (unit 3) are moderately susceptible to accelerated erosion.

Traverse condition summary (23 assessments):
Vegetation – good 70%; fair 17%; poor 13%.
Soil erosion – nil 92%; minor 4%; moderate 4%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Calcrete platform	1	–
2	Kopi bank	–	–
3	Alluvial plain	20	4
4	Flood plain	–	–
5	Saline alluvial plain	–	1
6	Drainage focus	–	–
7	Drainage tract/channel	2	–
	Total	23	5

Yewin land system

Unit	area (%)	Landform	Soil	Vegetation
1.	2%	**Calcrete platforms** – minor tracts of elevated calcrete residuals to 2 m high and extending to 2 km long and <1 km wide, usually located towards margin of system; level plains, with variable density mantles of calcrete pebbles and cobbles.	Shallow calcareous loams and red clayey sands on calcrete (5a, 2c).	Scattered (10-20% PFC) tall shrublands dominated by *Acacia tysonii* and *A. acuminata* subsp. *burkittii* (fine-leaf jam) (JAMS) or scattered (10-20% PFC) *Atriplex bunburyana* (silver saltbush) low shrubland (SSAS).
2.	1%	**Kopi banks** – occasional expanses of slightly elevated gypsiferous mounds (to 1 m high) between saline plains; often very saline with areas of dense surface crusting over powdery kopi.	Gypsiferous sediments (11).	Very scattered (2.5-10% PFC) halophytic shrublands dominated by *Lawrencia helmsii* (dunna-dunna) and *Halosarcia* spp. (samphire) (SAMP)
3.	50%	**Alluvial plains** – extensive level plains flanking and slightly higher then major flood plains (units 4-7), little relief except for occasional low sandy banks up to 1 m high or wind blown hummocks on degraded parts, subject to flooding.	Shallow (occasionally deep) duplex on hardpan (7c, 8).	Scattered to moderately close (10-30% PFC) low shrublands or mixed height shrublands dominated by *Maireana pyramidata* (sago bush) *Cratystylis subspinescens* (sage) or *Atriplex* spp. (saltbush) below *Acacia eremaea* (snakewood) and *A. masliniana* (spiny snakewood) tall shrubs (ASWS, PXHS, BLSS).
4.	20%	**Flood plains** – active flood plains adjacent to major water courses and slightly lower than unit 3, with widespread patterning of recently redistributed surface deposits.	Deep clays (9b).	Very scattered to moderately close (2.5-30% PFC) low halophytic shrublands with a sparse mid shrub layer of acacias (PXHS, SAMP).
5.	20%	**Saline alluvial plains** – level, low lying (and strongly saline) tracts between units 4 & 7; usually with only very sluggish through flow; prone to waterlogging.	Saline shallow clays with gypsum crystals in the subsoil (11).	Very scattered to scattered (2.5-20% PFC) low shrublands of *Halosarcia* spp. (samphire) with fringing communities of *Melaleuca, Frankenia, Atriplex* spp. (SAMP).
6.	2%	**Drainage foci** -		
		a) isolated discrete swampy drainage foci <250 m in diameter located mainly on alluvial plains and floodplains (units 3 & 4).	a) Deep clays (9b).	a) Moderately close to close (20-50% PFC) low shrublands dominated by *Atriplex amnicola* (river saltbush) or *Halosarcia* spp. with dense (>50% PFC) fringes of *Hakea preissii* (needlebush) or *Melaleuca* spp.
		b) more extensive, irregular claypans to 1 km long and 500 m wide with sluggish through drainage patterns and (locally) gilgai surfaces.	b) Deep clays and some cracking clays (9b, 10).	b) Scattered (10-20% PFC) woodlands dominated by *H. preissii, Acacia aneura*, (mulga) and *A. tetragonophylla* (curara).
7.	5%	**Drainage tracts and channels** – tracts to 1 km wide with channels to 100 m wide and sharply incised into hardpan or calcrete and carrying bedloads of coarse sand, calcrete and rubble. Frequent meanders and associated deposition around oxbows; also channels dispersing river flows onto flood plains.	Variable depth duplex soils or light clays overlying hardpan or calcrete (7c, 8, 9a, 9b).	Moderately close (20-30% PFC) tall shrublands of *Acacia* spp. with mostly halophytic undershrubs (DMCS). *Casuarina obesa* (swamp oak) along channels; also *Halosarcia* spp. low shrublands (SAMP).

YILGANGI LAND SYSTEM (21 km², 0.02% of the survey area)

(after Pringle *et al.* 1994)

Low breakaways with saline gravelly lower plains, supporting predominantly halophytic low shrublands.

Land type: 5

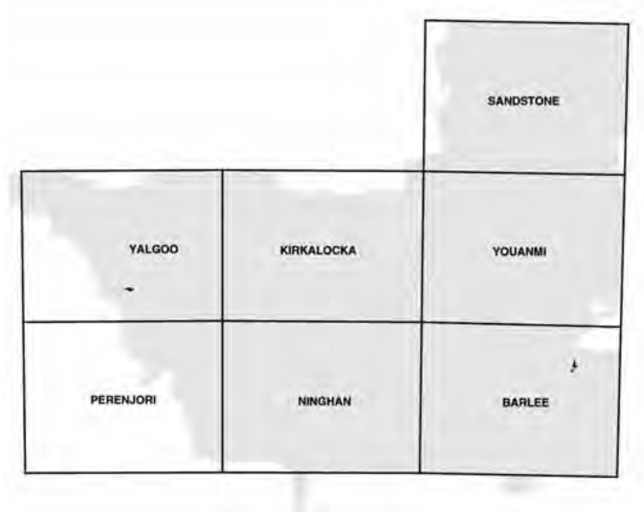
Geology: Archaean mafic metamorphic rocks, locally with banded iron formation, Tertiary ferruginous duricrusts, Quaternary alluvium with minor colluvium.

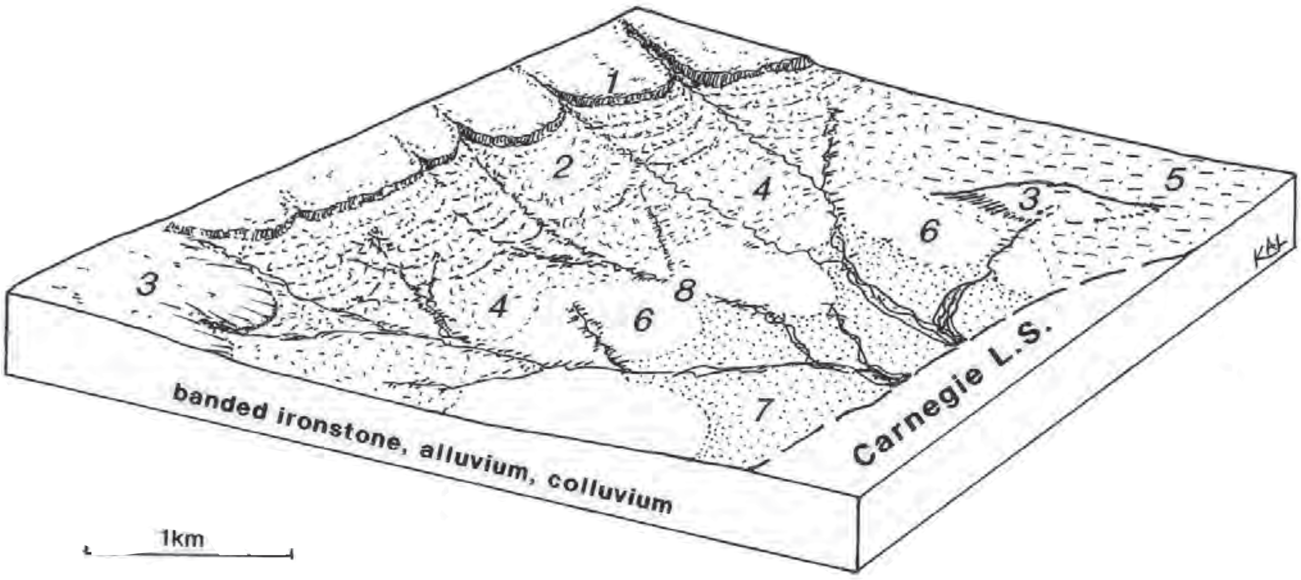
Geomorphology: Erosional and depositional surfaces; low breakaways (to 10 m relief) on deeply weathered greenstone with short footslopes derived from pallid zone materials upslope from level to very gently inclined alluvial plains with mantles of ironstone gravel and pebbles, and broad drainage tracts with occasional shallow channels.

Land management: Breakaway footslopes (unit 2), saline alluvial plains (unit 7) and narrow drainage zones (unit 8) have fragile soils and are susceptible to water erosion. The vegetation of this land system is particularly saline, however in proximity to permanent supplies of fresh water, it may be preferentially grazed by introduced and native animals and in such circumstances is susceptible to overgrazing if total grazing pressure is not controlled.

Traverse condition summary (3 assessments):
Vegetation – insufficient assessments.
Soil erosion – insufficient assessments.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Breakaway	–	–
2	Breakaway footslope	–	–
3	Low rise	1	1
4	Stony saline plain	2	1
5	Gravelly hardpan plain	–	–
6	Alluvial plain	–	–
7	Saline alluvial plain	–	–
8	Narrow drainage tract	–	–
	Total	3	2

Yilgangi land system

Unit	area (%)	Landform	Soil	Vegetation
1.	3%	**Breakaways** – narrow, stripped, duricrusts with escarpments (generally <10 m high), and stony scree slopes.	Rock outcrop and stony soils (1).	Scattered (10-20% PFC) eucalypt woodlands (GHMW) or scattered mixed shrublands (BRXS).
2.	5%	**Breakaway footslopes** – very gently inclined footslopes (to 500 m extent downslope) with ironstone pebble mantles.	Shallow duplex on greenstone (7b).	Scattered (10-20% PFC) predominantly *Halosarcia* spp. (samphire) low shrublands (SAMP).
3.	10%	**Low rises** – low rounded rises (<10 m relief and to 300 m wide), often with ferruginous duricrust.	Stony soils and shallow stony red earths (1, 5b).	Scattered (10-20% PFC) *Acacia aneura* (mulga) tall shrubs occasionally with weakly halophytic understorey shrubs (SIMS, USBS). Also scattered eucalypt woodlands (GHMW).
4.	22%	**Stony saline plains** – very gently inclined, slightly elevated plains, with mantles of abundant quartz and ironstone pebbles and cobbles.	Shallow duplex and shallow red earths on greenstone (7b, 5c).	Scattered (10-20% PFC) halophytic low shrublands with occasional tall shrubs (USBS, SBMS, SSMS)
5.	15%	**Gravelly hardpan plains** – very gently inclined plains subject to sheet flow, with mantles of abundant fine ironstone gravel.	Shallow red earths on hardpan (5c).	Scattered (10-20% PFC) *A. aneura* tall shrublands (LHMS).
6.	20%	**Alluvial plains** – level to very gently inclined plains with mantles of fine ironstone, and sometimes quartz gravel, receiving run-on from units 1, 2, 3 and 4.	Shallow saline duplex on greenstone (7b).	Very scattered to scattered (2.5-20% PFC) mixed low halophytic shrublands (PXHS, less frequently SAMP).
7.	20%	**Saline alluvial plains** – low lying plains with mantles of fine ironstone gravel, occurring downslope of unit 6.	Variable depth saline duplex or clays with stony mantles (7b, 8, 9a, 9b).	Very scattered to scattered (2.5-20% PFC) *Halosarcia* spp. low shrublands (SAMP).
8.	5%	**Narrow drainage tracts** – generally linear narrow (<500 m) drainage zones receiving concentrated run-on, with shallow (<30 cm deep) channels.	Shallow duplex on greenstone or hardpan (7b, 7c).	Scattered (10-20% PFC) halophytic low shrublands with occasional *A. aneura* tall shrubs (PXHS).

YOWIE LAND SYSTEM (9,189 km^2, 9.7% of the survey area)

(after Pringle *et al.* 1994)

Loamy plains supporting shrublands of mulga and bowgada with patchy wanderrie grasses.

Land type: 16

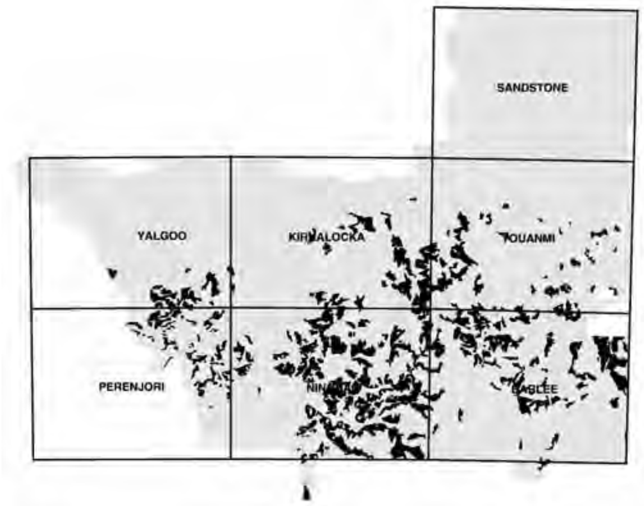
Geology: Quaternary sand and minor cemented alluvium.

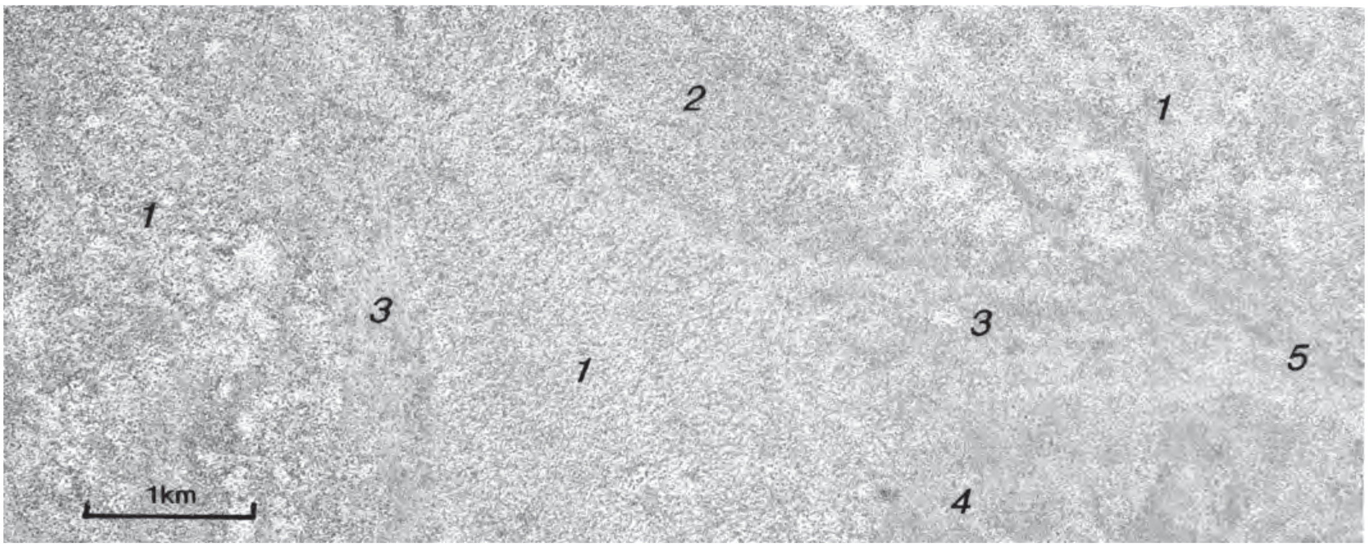
Geomorphology: Depositional surfaces; extensive level plains subject to very diffuse sheet flow.

Land management: This system is generally not susceptible to soil erosion.

Traverse condition summary (863 assessments):
Vegetation – good 50%; fair 36%; poor 14%.
Soil erosion – nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1	Loamy plain	576	27
2	Sand sheet	120	6
3	Hardpan plain	124	3
4	Gravelly plain	18	1
5	Narrow drainage tract	23	3
	Other	18	1
	Total	879 *	41

* 16 traverse points not assessed for condition.

Yowie land system

Unit	area (%)	Landform	Soil	Vegetation
1.	70%	**Loamy plains** – nearly level plains, locally subject to very diffuse sheet flow.	Variable depth red clayey sands, hardpan loams and red earths on hardpan (2d, 3a, 5d, 6a).	Moderately close (20-30% PFC) acacia tall shrublands, dominated by *Acacia ramulosa* (bowgada), *A. coolgardiensis* (sugar brother), *A. acuminat*a subsp. *burkittii* (fine-leaf jam) or *A. aneura* (mulga), often with emergent *A. aneura* trees (MUBW, PLMS, HCAS) or *Callitris glaucophylla* (native pine) trees (PINW), or mallee eucalypts (MAAS). Occasional *Eucalyptus loxophleba* (York gum) woodlands with acacia tall shrubs (PYAW).
2.	15%	**Sand sheets** – level sandy tracts in areas not receiving run-on.	Deep red clayey sands (3a).	Moderately close (20-30% PFC) acacia tall shrublands (SACS, SWGS) or acacia shrublands with mallee eucalypts (MAAS), rarely *Triodia basedowii* (hard spinifex) hummock grasslands with acacia and eucalypt overstoreys (SASP).
3.	10%	**Hardpan plains** – nearly level plains receiving run-on from adjacent uplands.	Shallow hardpan loams, red clayey sands and red earths on hardpan (5c, 2d, 4c). Deep red earths and sandy red earths (6a, 4).	Scattered (10-20% PFC) acacia tall shrublands (HPMS, HCAS, MUBW).
4.	2%	**Gravelly plains** – gently undulating plains with mantles of common fine ferruginous gravel.	Variable depth red clayey sands with ferruginous gravel over hardpan (2b).	Moderately close (20-30% PFC) *A. aneura* or *A. ramulosa* tall shrublands with occasional mallees, and sparse perennial grasses (SACS, MUBW).
5.	3%	**Narrow drainage tracts** – sparse, narrow (usually <250 m wide), unchannelled drainage zones, receiving concentrated run-on from adjacent uplands.	Deep red earths and juvenile alluvial deposits (6a, 12).	Moderately close to close (20-50% PFC) acacia tall shrublands with scattered trees and mallees (DRAS).

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Resource condition

A.M.E. Van Vreeswyk

The condition of the land resources in the survey area was assessed during field work. Traditional resource condition assessment in rangelands has focused on the use of land for pastoralism. In this report, an attempt has been made to broaden this perspective. As a result, the focus is on grazing impacts (or ecological integrity) rather than grazing value. This will increase the relevance beyond the pastoral industry, while still being amenable for pastoral interpretation.

Summary of traverse assessments

As indicated in the methodology chapter, traverse assessments were used to assess resource condition in the survey area. Assessments were done at 1 km intervals along pre-selected traverse routes. The condition of the perennial vegetation, and the type and extent of accelerated erosion was assessed within an area of 50 m radius around the vehicle at each kilometre interval. These assessments were visual subjective ratings. The rating system is described in the methodology chapter.

A total of 9,790 traverse points within the survey area were described and assessed for various biophysical parameters. However, the vegetation condition, and the type and the extent of soil erosion were only assessed at 9,435 of these points and are summarised in Tables 1, 2 and 3.

Seventy-seven per cent of all traverse assessments indicated vegetation was in the very good, good or fair categories. This is regarded as acceptable condition. The remaining 23% indicated poor or very poor condition vegetation, with either considerable loss of palatable perennial plants or general loss of perennial plants, or, in some cases, marked increases in cover by unpalatable species (‘woody weeds’).

Table 1.Summary of vegetation condition for the survey area derived from traverse assessments

Perennial vegetation condition	Proportion (%) of traverse assessments	
Very good	21.9	} 45.4
Good	23.5	
Fair	31.5	
Poor	18.1	} 23.1
Very poor	5.0	

Accelerated erosion was recorded at 5.3% of the traverse assessments: 4.9% of assessments indicated slight, minor or moderate erosion (i.e. <50% of the surface affected) and 0.4% showed severe or extreme erosion (>50% of the surface affected). Most of the accelerated erosion was caused by water, rather than wind. Sheeting, scalding and rilling were the most common types of erosion observed.

Table 2.Summary of accelerated soil erosion for survey area derived from traverse assessments

Extent of erosion	Proportion (%) of traverse assessments	
Nil	94.7	
Slight	1.6	} 3.6
Minor	2.0	
Moderate	1.3	
Severe	0.3	} 0.4
Extreme	0.1	

Table 3 Summary of the dominant types of accelerated erosion recorded in traverse assessments

Type of erosion	Proportion (%) of traverse assessments
Nil	94.7
Sheeting	2.5
Scalding	1.8
Rilling	0.7
Pedestalling	0.2
Gullying	0.1
Accelerated accretion of soil	<0.1

Water rather than wind is the main causal agent of accelerated erosion. Although not a widespread problem, gully erosion (as shown) can be locally severe.

Patterns of soil and vegetation condition

Vegetation condition and soil erosion are often closely related. Decline in vegetation condition involving decreases in total shrub cover, means that soil surfaces are increasingly unprotected from the effects of wind and water. Erosion is likely to commence (unless the surface is inherently resistant) and to accelerate if vegetation condition continues to decline.

However, in some instances of substantial grazing impact, vegetation succession is to dense 'woody weeds', which enhance soil stability. Table 4 shows the association between soil erosion and vegetation condition as seen during the survey.

Table 4. Average vegetation condition scores for classes of extent of soil erosion

Soil erosion	Average vegetation condition
Nil	2.5
Slight	3.5
Minor	4.0
Moderate	4.4
Severe	4.8
Extreme	5.0

Where 1 = very good condition, 2 = good, 3 = fair, 4 = poor and 5 = very poor.

Severely degraded and eroded areas

Areas of eroded soil surfaces larger than 40 ha in extent have been identified and mapped as being severely degraded and eroded (sde). These areas usually have little or no perennial vegetation remaining. They were interpreted from aerial photographs, and, in nearly all cases, the extent verified in the field. The distribution of severely degraded and eroded areas in the survey area is shown in Figure 1 and on the 1:500,000 scale land system map accompanying this report. The area totals about 144.6 km^2 which represents 0.15% of the survey area.

Severely degraded and eroded areas were identified in 23 of the 76 land systems, representing 11 of the 20 land types. The land systems with more than 1% severely degraded and eroded land are in land types characterised by alluvial plains which are subject to concentrated flow; mulga hardpan plains (land type 13), chenopod washplains (15), chenopod alluvial plains (17), and calcreted old drainage systems (18).

Severely degraded and eroded land was also identified in land systems in breakaway chenopod plains (4 and 5), low rises (8), stony non-chenopod plains (9), mulga plains and some wanderrie (14) and lake country (20).

Severely degraded and eroded areas were not mapped in any of the sandplain land types (10, 11 and 12), the granite plains and rises (6), undulating acacia country (7), sandy acacia plains with wanderrie (16), plains with eucalypt woodlands (19) or the hills with mixed shrublands or with chenopods (2 and 3). Only one of the 10 land systems in the acacia hills land type (1) contained severely degraded and eroded land.

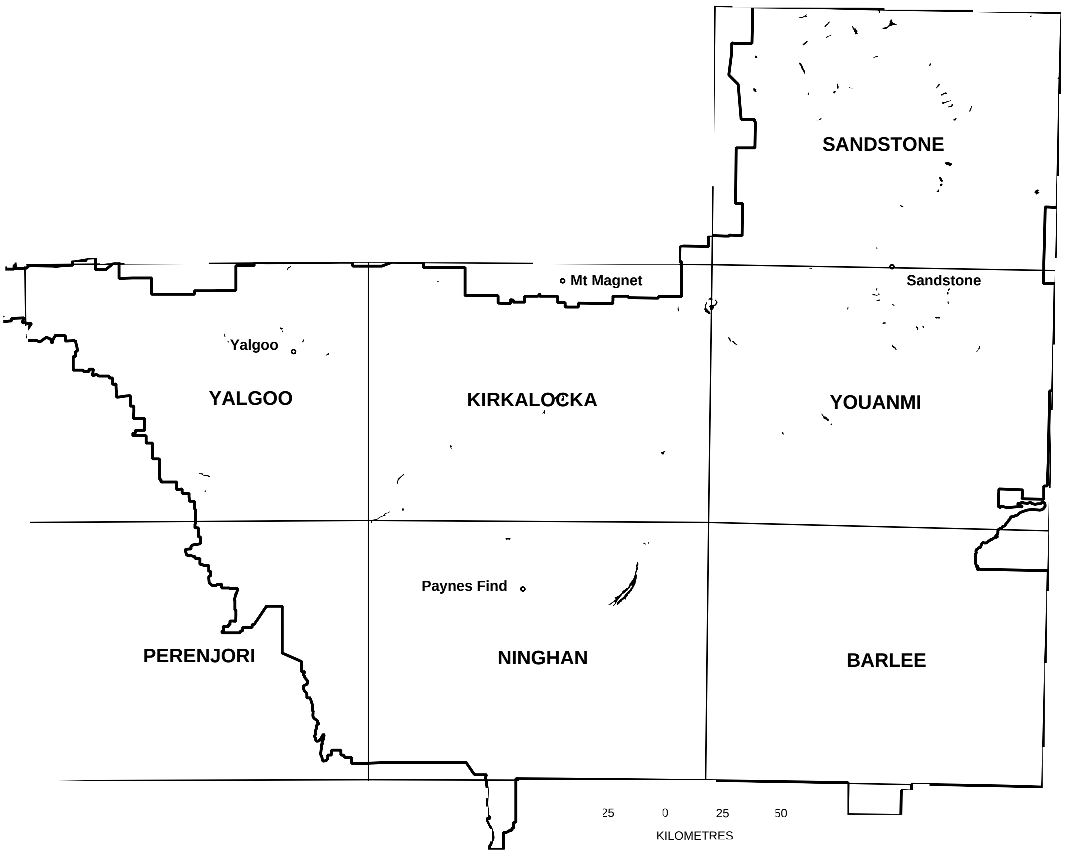
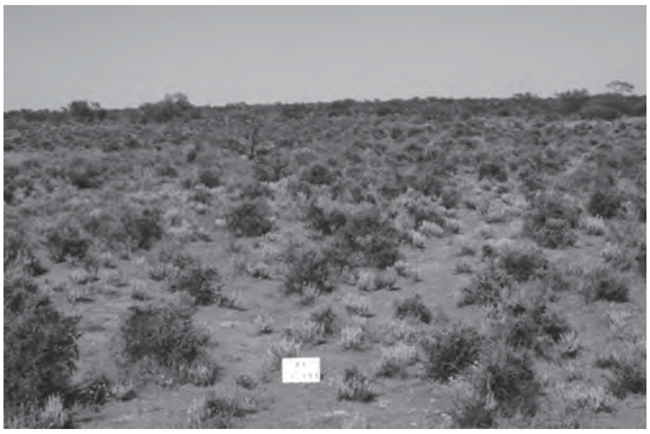


Figure 1. Areas mapped as being severely degraded and eroded (sde) within the survey area

Inappropriate management has resulted in severe degradation of this alluvial plain with extensive soil loss leaving hardpan exposed. A few residual surfaces remain, supporting only annuals in season.



This saltbush and bluebush community is in good condition. The diversity and density of perennial plants is optimal and there is no soil erosion.

Good condition areas

Figure 2 shows the distribution of traverse assessments of very good and good vegetation condition with no soil erosion. A large proportion of these points occurred in habitats which are largely unaltered by grazing, such as spinifex hummock grasslands and closed mixed shrublands.

Pringle (1995) used the inventory information gathered during the north-eastern Goldfields survey (Pringle *et al.* 1994) to assess the representativeness of the conservation reserve network in the area. The condition component of rangeland survey findings can be used to identify areas which are in good resource condition and thus are most suitable for reservation for conservation purposes. Habitats which are identified as being most substantially modified by grazing and hence most threatened by pastoralism (the most extensive

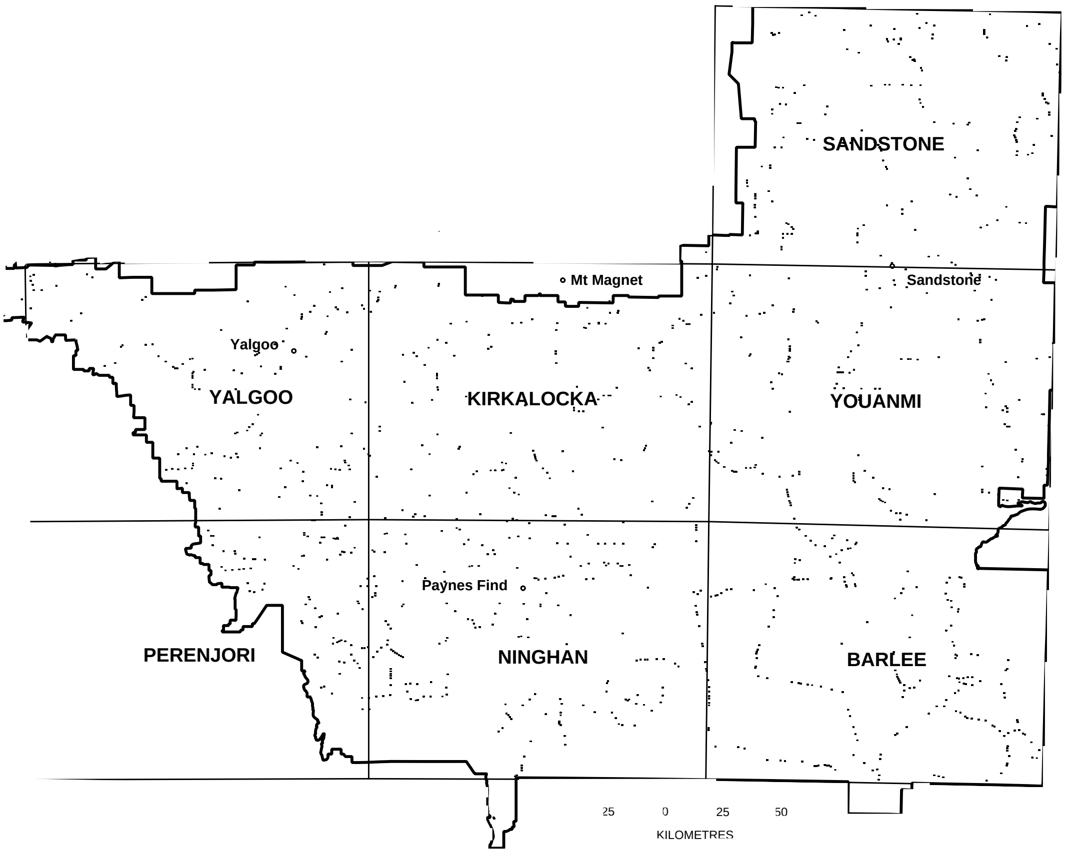


Figure 2. Traverse assessments of very good or good vegetation condition with no erosion within the survey area

land use in the area) may require urgent appraisal regarding inclusion in a reservation network.

Areas which could be used as references for grazing management can also be identified using the survey findings. These areas are important in providing reference data for land managers, researchers and administrators. Blood (1995) examined the findings of the Murchison rangeland survey (Curry et al. 1994) to identify, describe and map areas of rangeland in good condition within that region.

Comparison with other regional surveys

Table 5 shows a summary of the resource condition in the survey area compared with other surveys undertaken by Agriculture Western Australia and the Department of Land Administration. The resource condition score was determined by combining the perennial vegetation condition rating and extent of accelerated soil erosion for each traverse assessment, using the matrix shown in Table 6.

The Sandstone-Yalgoo-Paynes Find area is generally in better condition than most other survey areas. The proportion of land which has been mapped as being severely degraded and eroded (0.2%) is less than for all other survey areas except the eastern Nullarbor, where no areas of severely degraded and eroded land were identified.

Condition of land systems

The average number of traverse assessments for soil and vegetation condition per land system is 124, however, this varies between 0 and 863. Table 3 in the land systems chapter shows the sampling intensity for each system. Austin, Bunny, Lawrence and Narryer were not traversed. Ararak, Desdemona, Skipper, Teutonic and Yilgangi were assessed five times or less; for these land systems sampling intensity is too low for reasonable comparisons with other systems.

Table 7 shows the extent of severely degraded and eroded land mapped in each land system and Table 8 shows the condition of perennial vegetation and the extent of soil erosion for each land system based on traverse assessments.

Monitor and Wilson land systems have a large proportion (21.5 and 16.3% respectively) of severely degraded and eroded land. In the adjoining north-eastern Goldfields survey (Pringle et al. 1994) Monitor and Wilson were also the most degraded systems, comprising 62.5% of severely degraded area in that area. These two land systems are highly

Table 5. Resource condition summaries for regional rangeland surveys

Region surveyed (and year commenced)	Total area (km^2)	No. of traverse assessments	Severely degraded and eroded area (as mapped)		Resource condition classes (% of traverse assessments)		
			km^2	%	Good	Fair	Poor
Gascoyne (1969)	63,400	2,426	1,205*	1.9*	32	53	15
West Kimberley (1972)	89,600	4,532	2,000*	2.2*	20	50	30
Eastern Nullarbor (1974)	47,400	1,273	0	0	50	10	40
Ashburton (1976)	93,600	8,608	534	0.6	50	34	16
Carnarvon Basin (1980)	74,500	10,952	647	0.9	45	32	23
Murchison (1985)	88,360	13,441	1,560	1.8	21	37	42
Roebourne Plains (1987)	10,216	1,172	233	2.3	51	27	22
North-eastern Goldfields (1988)	100,570	10,470	452	0.4	39	32	29
Sandstone-Yalgoo-Paynes Find (1992)	94,710	9,435	145	0.2	45	32	23
All areas surveyed	661,840	62,309	6,778	1.0	39	34	27

* Not mapped, estimate only.

Table 6. Matrix used to determine resource condition score based on combined vegetation condition and extent of soil erosion scores

		Condition of vegetation Very good or Good	Fair	Poor or Very poor
	Nil	Good (1)	Fair (2)	Poor (3)
Extent of soil erosion	Slight or Minor	Good (1)	Fair (2)	Poor (3)
	Moderate	Fair (2)	Poor (3)	Poor (3)
	Severe or Extreme	Poor (3)	Poor (3)	Poor (3)

susceptible to erosion because they consist of alluvial plains which are subject to high rates of run-on; have inherently susceptible duplex soils and surfaces which are not protected by stony mantles; and support halophytic vegetation which is subject to preferential grazing.

Other land systems with >1% severely degraded and eroded areas were Ero, Yalluwin, Merbla and Cunyu. These four systems also support predominantly halophytic shrublands which are preferentially grazed by stock, and are dominated by soils which are inherently susceptible to erosion.

Table 7. The extent of severely degraded and eroded land (sde) within each land system

Land system	Area (km^2)	sde (ha)	%
Ararak	67	0	0
Austin	5	0	0
Bandy	638	0	0
Bannar	6,937	0	0
Bevon	314	0	0
Brooking	366	0	0
Bullimore	6,249	0	0
Bunny	16	0	0
Campsite	173	0	0
Carnegie	8,649	367	0.04
Challenge	3,655	0	0
Cosmo	50	0	0
Cunyu	358	364	1.02
Deadman	214	0	0
Desdemona	40	0	0
Doney	1,287	0	0
Dryandra	353	0	0
Ero	531	3,989	7.51
Euchre	1,769	0	0
Felix	112	9	0.08
Gabanintha	1,145	0	0
Gransal	800	389	0.49
Graves	172	0	0
Gumbreak	382	124	0.32
Hamilton	325	0	0
Hootanui	423	79	0.19
Illaara	202	0	0
Joseph	4,612	0	0
Joy	19	0	0
Jundee	1,333	1,211	0.91
Kalli	4,954	0	0
Lawrence	4	0	0
Marlow	137	0	0
Marmion	4,150	0	0
Melaleuca	129	0	0
Merbla	360	1,252	3.48
Mileura	700	12	0.02
Monitor	66	1,414	21.47
Monk	1,822	191	0.10
Moriarty	825	0	0
Mulline	78	0	0
Nallex	439	58	0.13
Naluthanna	277	0	0
Narryer	19	0	0
Nerramyne	1,650	0	0
Norie	755	0	0
Nubev	133	0	0
Olympic	1,135	0	0
Pindar	1,519	0	0
Racecourse	53	0	0
Rainbow	666	86	0.13
Ranch	298	11	0.04
Roderick	47	0	0
Sherwood	3,458	1,292	0.37
Singleton	238	0	0
Skipper	19	0	0
Steer	133	115	0.86
Tallering	329	0	0
Tango	86	0	0
Tealtoo	693	0	0
Teutonic	78	0	0
Tindalarra	4,349	1,397	0.32
Tyrrell	1,960	0	0
Violet	882	0	0
Waguin	1,249	0	0
Watson	155	0	0
Wilson	37	599	16.31
Wiluna	386	186	0.48
Windarra	370	0	0
Woodline	5,856	44	0.01
Yalluwin	247	890	3.61
Yanganoo	3,276	386	0.12
Yarrameedie	66	0	0
Yewin	140	0	0
Yilgangi	21	0	0
Yowie	9,189	0	0
Totals	94,629	14,465	

Table 8. The condition of perennial vegetation and extent of soil erosion on each land system (derived from traverse assessments)

		Condition of perennial vegetation (%)				Extent of soil erosion (%)			
Land system	No. of assessments	Good or very good	Fair	Poor	Very poor	Nil	Slight or minor	Moderate	Severe or extreme
Ararak	5	60	40	0	0	100	0	0	0
Austin	0	–	–	–	–	–	–	–	–
Bandy	51	69	25	6	0	100	0	0	0
Bannar	362	88	9	2	1	100	0	0	0
Bevon	16	44	25	19	12	100	0	0	0
Brooking	31	65	3	26	6	97	3	0	0
Bullimore	231	89	3	7	1	100	0	0	0
Bunny	0	–	–	–	–	–	–	–	–
Campsite	29	34	38	28	0	97	3	0	0
Carnegie	567	62	27	9	2	93	5	1	1
Challenge	448	31	42	22	5	96	2	1	1
Cosmo	10	60	20	10	10	100	0	0	0
Cunyu	85	13	17	42	28	87	10	1	2
Deadman	36	78	11	11	0	100	0	0	0
Desdemona	3	0	33	67	0	100	0	0	0
Doney	133	50	34	14	2	98	1	1	0
Dryandra	27	81	15	4	0	100	0	0	0
Ero	138	31	36	21	12	58	25	12	5
Euchre	188	72	22	4	2	99	1	0	0
Felix	16	63	19	12	6	100	0	0	0
Gabanintha	102	32	54	9	5	98	2	0	0
Gransal	178	26	39	26	9	79	15	4	2
Graves	25	28	68	4	0	100	0	0	0
Gumbreak	62	42	23	27	8	87	10	3	0
Hamilton	70	21	49	26	4	95	4	1	0
Hootanui	92	12	42	36	10	85	10	5	0
Illaara	21	62	38	0	0	100	0	0	0
Joseph	296	87	12	1	0	100	0	0	0
Joy	6	83	17	0	0	100	0	0	0
Jundee	161	42	34	14	10	95	3	1	1
Kalli	435	69	24	6	1	100	0	0	0
Lawrence	0	–	–	–	–	–	–	–	–
Marlow	35	3	34	46	17	83	11	3	3
Marmion	120	84	13	3	0	100	0	0	0
Melaleuca	13	23	39	38	0	100	0	0	0
Merbla	65	19	29	34	18	72	12	14	2
Mileura	189	36	30	25	9	86	10	4	0
Monitor	12	0	8	42	50	50	17	17	16
Monk	251	24	39	28	9	99	1	0	0
Moriarty	127	42	35	18	5	99	1	0	0
Mulline	12	8	50	34	8	100	0	0	0
Nallex	99	8	41	33	18	86	12	2	0
Naluthanna	28	7	36	25	32	86	7	7	0
Narryer	0	–	–	–	–	–	–	–	–
Nerramyne	181	54	36	9	1	99	1	0	0
Norie	33	61	36	3	0	97	3	0	0
Nubev	30	20	34	33	13	94	6	0	0
Olympic	127	61	35	4	0	99	1	0	0
Pindar	128	45	41	13	1	100	0	0	0
Racecourse	10	60	20	10	10	90	0	0	10
Rainbow	105	24	45	26	5	97	2	0	1
Ranch	49	12	53	23	12	92	8	0	0
Roderick	13	30	62	8	0	100	0	0	0
Sherwood	413	43	30	21	6	91	6	3	0
Singleton	26	61	31	8	0	100	0	0	0
Skipper	2	100	0	0	0	100	0	0	0
Steer	10	30	20	20	30	40	30	10	20
Tallering	29	69	31	0	0	100	0	0	0
Tango	25	24	36	20	20	80	16	4	0

Table 8. continued . . .

Land system	No. of assessments	Condition of perennial vegetation (%) Good or very good	Fair	Poor	Very poor	Extent of soil erosion (%) Nil	Slight or minor	Moderate	Severe or extreme
Tealtoo	96	56	32	12	0	100	0	0	0
Teutonic	4	0	50	25	25	100	0	0	0
Tindalarra	710	17	45	30	8	89	7	3	1
Tyrrell	177	80	15	4	1	100	0	0	0
Violet	104	37	29	27	7	96	4	0	0
Waguin	123	60	26	11	3	99	0	1	0
Watson	12	25	42	17	16	100	0	0	0
Wilson	24	21	37	17	25	71	17	8	4
Wiluna	48	27	27	23	23	90	6	2	2
Windarra	56	22	23	41	14	91	4	2	3
Woodline	695	27	41	27	5	99	1	0	0
Yalluwin	34	29	26	24	21	76	18	0	6
Yanganoo	479	29	28	37	6	94	5	1	0
Yarrameedie	28	25	39	18	18	93	4	3	0
Yewin	23	70	17	13	0	92	4	4	0
Yilgangi	3	67	0	33	0	100	0	0	0
Yowie	863	50	36	14	0	100	0	0	0
Totals	9,435	45.4	31.5	18.1	5.0	94.7	3.6	1.3	0.4

Table 9. Land systems ranked according to resource condition score

Land system	No. of. assessments	Resource condition % good (1)	% fair (2)	% poor (3)	Average resource condition score
Marmion	120	84	13	3	1.13
Joseph	296	87	12	1	1.14
Bannar	362	88	9	3	1.15
Joy	6	83	17	0	1.17
Bullimore	231	89	3	8	1.19
Dryandra	27	81	15	4	1.23
Tyrrell	177	80	15	5	1.25
Tallering	29	69	31	0	1.31
Euchre	188	73	22	5	1.32
Deadman	36	78	11	11	1.33
Bandy	51	69	25	6	1.37
Kalli	435	69	24	7	1.38
Illaara	21	62	38	0	1.38
Norie	33	61	36	3	1.42
Olympic	127	61	35	4	1.43
Yewin	23	70	17	13	1.43
Singleton	26	61	31	8	1.47
Carnegie	567	62	27	11	1.49
Waguin	123	60	26	14	1.54
Felix	16	63	19	18	1.55
Tealtoo	96	56	32	12	1.56
Nerramyne	181	54	36	10	1.56
Cosmo	10	60	20	20	1.60
Racecourse	10	60	20	20	1.60
Yowie	863	50	36	14	1.64
Doney	133	50	34	16	1.66
Brooking	31	65	3	32	1.67
Pindar	128	45	42	13	1.68
Graves	25	28	68	4	1.76
Roderick	13	31	61	8	1.77
Moriarty	127	42	35	23	1.81
Jundee	161	42	34	24	1.82
Gabanintha	102	32	54	14	1.82
Sherwood	413	43	30	27	1.84
Bevon	16	44	25	31	1.87

Table 9. continued . . .

Land system	No. of. assessments	Resource condition % good (1)	% fair (2)	% poor (3)	Average resource condition score
Gumbreak	62	42	23	35	1.93
Campsite	29	34	38	28	1.94
Challenge	448	31	42	27	1.96
Violet	104	37	29	34	1.97
Mileura	189	35	31	34	1.99
Ero	138	31	34	35	2.04
Woodline	695	27	41	32	2.05
Rainbow	105	24	45	31	2.07
Watson	12	25	42	33	2.08
Gransal	178	26	39	35	2.09
Hamilton	70	21	49	30	2.09
Yarrameedie	28	25	39	36	2.11
Yalluwin	34	29	26	44	2.13
Monk	251	24	39	37	2.13
Yanganoo	479	29	28	43	2.14
Melaleuca	13	23	39	38	2.15
Tango	25	24	36	40	2.16
Wiluna	48	27	27	46	2.19
Steer	10	30	20	50	2.20
Tindalarra	710	17	45	38	2.21
Wilson	24	21	37	42	2.21
Ranch	49	12	53	35	2.23
Nubev	30	20	33	47	2.27
Windarra	56	22	23	55	2.33
Hootanui	92	12	42	46	2.34
Mulline	12	8	50	42	2.34
Merbla	65	18	28	54	2.36
Nallex	99	8	40	52	2.44
Naluthanna	28	7	36	57	2.50
Cunyu	85	13	16	71	2.58
Marlow	35	3	34	63	2.60
Monitor	12	0	8	92	2.92

The average resource condition score for each of the land systems which were sufficiently traversed was derived using the matrix to combine vegetation condition and extent of soil erosion (see Table 6). Table 9 shows these land systems ranked according to their average resource condition score.

Of the 67 land systems considered, 18 were closest to good resource condition (average score between 1.0 and 1.5), 46 were closest to fair condition (average score between 1.5 and 2.5) and 3 were closest to poor condition (average score between 2.5 and 3).

Condition of land systems according to pastoral potential

Land systems were grouped according to their pastoral potential (Table 10). This is discussed in the companion report on pastoral management in the survey area (Van Vreeswyk and Godden 1998). The average resource condition score for the groups is summarised in Table 11. The land of very high pastoral potential (represented by Merbla) was in the worst resource condition and had the highest proportion of severely degraded and eroded land.

The high, moderately high, moderate and low pastoral potential groups were on average closest to fair condition, and had < 0.6% of their areas identified as severely degraded and eroded.

The very low and negligible pastoral potential groups were on average closest to good condition, with no areas of severely degraded and eroded land identified.

The high pastoral potential group was on average, in better resource condition than the moderately high and moderate groups. This is similar to the situation in the north-eastern Goldfields survey area (Pringle *et al.* 1994) and may reflect the difficulty of obtaining good quality stock water supplies in these areas.

Condition of habitats and habitat groups

The land unit and habitat at each traverse assessment was recorded. Habitats are an ecological classification at a plant community/landform scale (see the ecological assessment chapter).

The vegetation condition and extent of soil erosion of the habitats based on the traverse assessments are presented in Table 12. The habitat groups and numbers are those used in the ecological assessment chapter, where each habitat is defined and discussed. Very good and good ratings for condition of perennial vegetation were combined as good. Slight and minor erosion ratings, and severe and extreme erosion ratings were combined as minor and severe respectively for extent of soil erosion. Two habitats are grouped in three cases because they were not differentiated in the traverse recordings.

Table 10. Land systems in each pastoral potential group

Pastoral potential	Land systems			
Very high	Merbla			
High	Austin Carnegie Ero	Gumbreak Joy Mileura	Racecourse Roderick	Steer Yewin
Moderately high	Bunny Campsite Cunyu Doney Euchre Gransal	Graves Hootanui Lawrence Marlow Monitor	Moriarty Nallex Nubev Sherwood Skipper	Tango Tindalarra Wilson Wiluna Yilgangi
Moderate	Ararak Bandy Challenge Cosmo Deadman Desdemona	Felix Hamilton Illaara Jundee Melaleuca Monk	Narryer Olympic Pindar Rainbow Ranch Violet	Waguin Windarra Woodline Yalluwin Yanganoo
Low	Bannar Bevon Gabanintha Kalli	Mulline Naluthanna Nerramyne	Norie Singleton Tealtoo	Teutonic Yarrameedie Yowie
Very low	Brooking Bullimore	Dryandra Marmion	Tallering Tyrrell	Watson
Negligible	Joseph			

Table 11. Average resource condition scores for land systems grouped according to pastoral potential (derived from traverse assessments)

Pastoral potential	Area (km2)	No. of assess-ments	Resource condition Good (1)	Fair (2)	Poor (3)	Average score	sde (ha)	% sde
Very high	360	65	18	28	54	2.36	1,252	3.48
High	8,117	1,018	51	29	20	1.69	4,607	0.57
Moderately high	14,959	2,258	30	36	34	2.04	5,778	0.39
Moderate	24,103	2,985	34	36	30	1.96	2,828	0.12
Low	26,373	2,186	59	30	11	1.52	0	0
Very low	13,562	627	82	11	7	1.25	0	0
Negligible	4,612	296	88	11	1	1.13	0	0
Total	92,086˜	9,435	45	32	23	1.78	14,465	0.16

˜ this summary does not include the 2,542 km^2 of lake bed in Carnegie land system, which has no pastoral potential.

Table 12. The condition of perennial vegetation and extent of soil erosion for habitats (derived from traverse assessments)

Habitat group	Habitat no.	Habitat	No. of assessments	Condition of perennial vegetation (%)				Extent of erosion (%)			
				Good	Fair	Poor	Very poor	Nil	Minor	Moderate	Severe
A	1	BRXS	92	66	28	5	1	100	0	0	0
	2	GHAS	38	21	63	16	0	100	0	0	0
	3	GHMW	16	38	31	25	6	100	0	0	0
	4	GRHS	6	83	17	0	0	100	0	0	0
	5/6	SIAS/SIMS	124	59	31	9	1	100	0	0	0
	7	UFTH	0	–	–	–	–	–	–	–	–
		IRMS	0	–	–	–	–	–	–	–	–
B	8	GABS	58	91	9	0	0	100	0	0	0
	9	SAES	264	40	32	21	7	98	2	0	1
	10	SGRS	399	38	42	16	4	100	0	0	0
		GMAS	0	–	–	–	–	–	–	–	–
C	11	BCLS	18	39	11	22	28	67	17	17	0
	12	BECW	0	–	–	–	–	–	–	–	–
	13	SBMS	248	14	30	33	23	80	15	4	1
	14	USBS	17	35	24	29	12	94	6	0	0
		SSMS	0	–	–	–	–	–	–	–	–
D	15	ASWS	229	33	29	29	9	81	14	5	0
	16	BLSS	64	94	3	3	0	97	3	0	0
	17	GGLS	12	0	25	25	50	100	0	0	0
	18/19	PECW/PYCW	121	46	32	18	4	99	1	0	0
	20	PSAS	89	25	29	33	13	70	21	9	0
	21	PXHS	335	43	29	16	12	72	16	7	5
	22	SAMP	100	89	5	6	0	95	5	0	0
	23	SBLS	88	57	37	6	0	100	0	0	0
	24	SSAS	51	74	16	6	4	80	16	2	2
	25	DACS	20	50	35	15	0	95	5	0	0
		FRAN	32	38	47	12	3	66	22	12	0
		MHHS	30	40	33	20	7	70	17	13	0
		POMS	0	–	–	–	–	–	–	–	–
E	26	CAPW	35	9	34	40	17	100	0	0	0
	27	JAMS	77	10	18	46	26	92	7	1	0
		KOPI	9	89	11	0	0	100	0	0	0
		CCAS	103	70	22	6	2	100	0	0	0
F	28	MESS	7	29	71	0	0	100	0	0	0
	29	ACGU	2	0	0	50	50	0	50	0	50
		PDFT	0	–	–	–	–	–	–	–	–
		CGSW	0	–	–	–	–	–	–	–	–
		LISW	2	50	50	0	0	100	0	0	0
G	30/31	HPMS/HCAS	1,437	21	42	32	5	95	4	1	0
	32	HMCS	166	30	31	24	15	75	16	7	2
	33	DRAS	253	25	46	25	4	93	6	1	0
	34	CBKW	11	55	9	27	9	82	9	0	9
	35	GRMU	21	48	33	19	0	100	0	0	0
	36	LHMS	175	33	39	22	6	96	3	0	1
	37	MUBW	1,015	31	41	24	4	100	0	0	0
	38	WABS	50	22	42	32	4	100	0	0	0
		CBBS	0	–	–	–	–	–	–	–	–
H	39	PYAW	281	39	46	14	1	100	0	0	0
	40	PINW	170	65	26	8	1	100	0	0	0
	41	PLMS	485	46	83	4	1	100	0	0	0
	42	MUWA	107	51	30	17	2	100	0	0	0
I	43	SASP	325	100	0	0	0	100	0	0	0
	44	SAMU	130	100	0	0	0	100	0	0	0
J	45.	SWGS	310	70	22	8	0	100	0	0	0
	46	SACS	366	92	7	1	0	100	0	0	0
	47	LACS	40	43	42	13	2	100	0	0	0
	48	LSHE	114	95	4	1	0	100	0	0	0
	49	SCMS	88	100	0	0	0	100	0	0	0
	50	MAAS	298	87	10	3	0	100	0	0	0
		SDSH	4	100	0	0	0	100	0	0	0
		Total	8,532								

Table 13. Habitats ranked according to their resource condition score

Habitat group	Habitat no.	Habitat	No. of assessments	Resource condition (%) Good (1)	Fair (2)	Poor (3)	Average score
I	44	SAMU	130	100	0	0	1.00
I	43	SASP	325	100	0	0	1.00
J	49	SCMS	88	100	0	0	1.00
J	48	LSHE	114	95	4	1	1.06
D	16	BLSS	64	94	3	3	1.09
B	8	GABS	58	91	9	0	1.09
J	46	SACS	366	92	7	1	1.09
E		KOPI	9	89	11	0	1.11
J	50	MAAS	298	87	10	3	1.16
A	4	GRHS	6	83	17	0	1.17
D	22	SAMP	100	89	5	6	1.17
D	24	SSAS	51	74	16	10	1.36
E		CCAS	103	70	22	8	1.38
J	45	SWGS	310	70	22	8	1.38
A	1	BRXS	92	66	28	6	1.40
H	40	PINW	170	65	26	9	1.44
D	23	SBLS	88	57	37	6	1.49
A	5/6	SIAS/SIMS	124	59	31	10	1.51
D	25	DACS	20	50	35	15	1.65
H	42	MUWA	107	51	30	19	1.68
H	41	PLMS	485	46	39	15	1.69
G	35	GRMU	21	48	33	19	1.71
F	28	MESS	7	29	71	0	1.71
J	47	LACS	40	43	42	15	1.72
D	18/19	PECW/PYCW	121	46	32	22	1.76
H	39	PYAW	281	39	46	15	1.76
G	34	CBKW	11	55	9	36	1.81
B	10	SGRS	399	38	42	20	1.82
D	21	PXHS	335	43	29	28	1.85
D		FRAN	32	38	37	25	1.87
B	9	SAES	264	40	32	28	1.88
A	3	GHMW	16	38	31	31	1.93
D		MHHS	30	40	27	33	1.93
A	2	GHAS	38	21	63	16	1.95
G	36	LHMS	175	33	39	28	1.95
G	37	MUBW	1015	31	41	28	1.97
C	11	BCLS	18	39	11	50	2.01
G	33	DRAS	253	25	46	29	2.04
D	15	ASWS	229	33	29	38	2.05
C	14	USBS	17	35	24	41	2.06
G	32	HMCS	166	30	31	39	2.09
G	38	WABS	50	22	42	36	2.14
G	30/31	HPMS/HCAS	1437	21	42	37	2.16
D	20	PSAS	89	25	29	46	2.21
C	13	SBMS	248	14	30	56	2.42
E	26	CAPW	35	9	34	57	2.48
E	27	JAMS	77	10	18	72	2.62
D	17	GGLS	12	0	25	75	2.75

The average resource condition score for each habitat was derived using the matrix to combine vegetation condition and extent of soil erosion (see Table 6). Table 13 shows the habitats which were sufficiently traversed (assessed >5 times) ranked according to their average resource condition score.

Of the 51 habitats considered, 17 were closest to good resource condition (average score between 1.0 and 1.5), 32 were closest to fair condition (average score between 1.5 and 2.5) and 2 were closest to poor condition (average score between 2.5 and 3).

Seven of the habitats closest to good resource condition are sandplain habitats (groups I and J). They support spinifex hummock grasslands and sclerophyll shrublands or woodlands whose component species are mostly unattractive to livestock and are largely unaltered by grazing. They are susceptible to fire, and vegetation composition and structure can vary considerably depending on fire history.

Four of the 17 habitats closest to good resource condition have high pastoral value on alluvial plains supporting chenopod shrublands (BLSS, SAMP, SSAS and SBLS) of habitat group D. Of the remaining nine habitats in this group seven are closest to fair resource condition, one (GGLS) is closest to poor condition and one was not sampled. Most habitats in group D are preferentially grazed by stock and have duplex soils which are inherently susceptible to erosion, but the condition data presented here suggest that they have not been universally overgrazed and degraded. This information has useful implications when considering future conservation options and also suggests that, with appropriate management, some sensitive habitats can be maintained under pastoralism. However, one important habitat from group D, namely *Gilgai grassy low shrubland* (GGLS), is in the poorest condition of the survey area and appears to have been considerably modified by grazing. This habitat was the most pastorally productive but it is now largely degraded to annual herbfields and partly invaded by the introduced weed saffron thistle (*Carthamus lanatus*). In pastoral terms it is still productive as it produces abundant annual herbage in season, but now has little drought durability. Due to its clay soils and flat topography there is generally no accelerated erosion.

The *Calcrete platform jam shrubland* (JAMS) habitat is in the second poorest condition in the survey area. In common with other habitats based on calcareous plains and platforms (group E) it supports vegetation which is highly attractive to, and therefore preferentially grazed by stock and native and feral animals. Low shrub layers are often severely altered and, although soils are generally stable, minor erosion can occur.

Group C comprises habitats with moderately high to high pastoral potential. Those sampled from within this group (BCLS, SBMS and USBS) show fair average condition scores but are ranked low compared with other habitats (see Table 11) and are more degraded than those with lower pastoral potential. This supports findings from other rangeland surveys (Payne *et al.* 1987, Curry *et al.* 1994) where country with low pastoral potential was in the best (least impacted) condition compared to high pastoral potential country. However, this is not exclusively the case in this survey area as indicated by the highly variable condition of habitats in the high pastoral potential group D as previously described. Some habitats within group D are in considerably better condition than those (e.g. HPMS/HCAS) in the moderate pastoral potential group G. This situation may reflect the ease of finding water and longer history of use on broad sheet flow plain habitats (group G) compared with saline lake frontage habitats of group D where good quality stock water supplies may be difficult to find. The more productive habitats may have had a more conservative stocking history reflecting an ethic of protecting the more sensitive, high value country. Stocking rate workshops in this survey area (Pringle and Riches 1996), and in the adjoining north-eastern Goldfields survey (Pringle *et al.* 1992) have shown that pastoralists allocated more conservative carrying capacities to their most productive country when compared with those recommended by Agriculture Western Australia.

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Appendices

1. **Plant species lists (A.M.E. Van Vreeswyk[1])**
   - **(i) Perennial plant species recorded in the survey area**
   - **(ii) Common perennial plants in the survey area**
   - **(iii) Annual species collected during the survey or known to occur in the survey area**
2. **Land system map (1:500,000 scale)**

[1]Natural Resource Management Services, Agriculture Western Australia

Appendix 1(i). Perennial plant species recorded in the survey area

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	F 3 Habitat group	G	H	I	J	4 Total sites
Adiantaceae													
Cheilanthes austrotenuifolia	3068	F	36	8	1	–	–	–	13	2	–	10	70
Cheilanthes lasiophylla	3547	F	4	–	–	–	–	–	–	–	–	–	4
Cheilanthes sieberi subsp. *sieberi*	3548	F	1	–	–	–	–	–	–	–	–	–	1
Aizoaceae													
Carpobrotus modestus	2414	LS	–	–	1	–	–	–	–	–	–	–	1
Disphyma crassifolium	2009	LS	–	–	–	4	–	–	–	–	–	–	4
Gunniopsis quadrifida	2152	LS	–	–	1	26	–	–	–	–	–	–	27
Amaranthaceae													
Ptilotus albidus	3702	LS	–	–	–	–	–	–	–	–	–	–	–
Ptilotus divaricatus	2194	S	2	1	3	34	2	5	19	5	–	2	73
Ptilotus drummondii		LS	2	2	–	–	–	–	5	2	–	2	13
Ptilotus helichrysoides	3315	LS	–	–	–	–	–	–	–	–	–	–	–
Ptilotus obovatus	2050	LS	98	58	36	102	22	8	145	55	6	26	556
Ptilotus polakii	3026	LS	1	–	–	3	–	–	–	–	–	–	4
Ptilotus roei	3121	H	–	–	–	–	–	–	–	–	–	–	–
Ptilotus rotundifolius		S	–	1	–	–	–	–	–	–	–	–	1
Ptilotus schwartzii	30244	LS	27	22	–	–	1	–	17	9	3	11	90
Ptilotus schwartzii var. *georgei*	3423	LS	–	–	–	–	–	–	–	–	–	–	–
Ptilotus schwartzii var. *schwartzii*	3982	LS	–	–	–	–	–	–	–	–	–	–	–
Anthericaceae													
Arthropodium capillipes	3771	H	2	2	–	–	–	–	2	–	–	1	7
Borya sphaerocephala	3258	LS	13	23	–	–	–	–	1	–	–	7	44
Laxmannia sp.	3560	LS	–	–	–	–	–	–	–	–	–	–	–
Thysanotus manglesianus	3299	V	7	1	–	4	–	–	16	5	2	17	52
Apiaceae													
Platysace effusa	3494	LS	–	–	–	–	–	–	–	–	1	1	2
Xanthosia bungei	3866	S	–	–	–	–	–	–	–	–	–	–	–
Apocynaceae													
Alyxia buxifolia	30062	S	8	–	–	2	2	–	–	15	1	2	30
Alyxia tetanifolia	30261	S	–	–	–	–	–	–	1	–	–	1	2
Asclepiadaceae													
Cynanchum floribundum	3126	V	–	–	–	–	–	–	–	–	1	–	1
Marsdenia australis		V	2	4	2	9	2	1	22	3	–	1	46
Marsdenia graniticola	3502	S	–	–	–	–	–	–	–	–	–	–	–
Rhyncharrhena linearis	3543	V	2	–	1	–	–	–	6	1	–	2	12
Sarcostemma viminale subsp. *australe*	3770	S	1	–	–	–	–	–	–	–	–	–	1
Asteraceae													
Asteridea chaetopoda	3509	LS	–	–	–	–	1	–	–	–	–	–	1
Chrysocephalum puteale	2072	LS	6	1	–	–	–	–	–	–	–	1	8
Cratystylis subspinescens		S	–	–	5	34	–	4	–	–	–	–	43
Erodiophyllum acanthocephalum	30028	LS	–	–	–	–	–	–	–	–	–	–	–
Minuria cunninghamii	3090	LS	3	–	–	2	–	–	1	7	–	10	23
Minuria leptophylla	3508	LS	4	–	1	2	1	–	7	8	–	3	26
Olearia dampieri subsp. *eremicola*	3588	S	–	–	–	2	–	–	–	–	–	–	2
Olearia decurrens	6912	LS	–	–	–	–	–	–	–	–	–	–	–
Olearia muelleri	3843	LS	6	–	1	17	4	–	5	24	1	2	60
Olearia pimeleoides	2002	LS	6	–	2	11	4	–	9	35	5	13	85
Olearia stuartii	3461	LS	8	–	1	–	–	–	1	1	–	–	11
Olearia subspicata	30254	S	–	–	–	–	–	–	–	–	2	–	2
Boraginaceae													
Halgania cyanea	30253	LS	–	–	–	–	–	–	–	–	1	–	1
Halgania viscosa	2211	LS	–	–	–	–	–	–	–	–	1	–	1
Brassicaceae													
Lepidium platypetalum	3120	LS	–	–	2	1	–	–	–	–	–	–	3
Caesalpiniaceae													
Senna artemisioides subsp. *artemisioides*	3470	S	13	–	1	6	2	–	9	–	–	–	31
Senna artemisioides subsp. *coriacea*	2278	S	–	–	–	–	–	–	–	–	–	–	–
Senna artemisioides subsp. *filifolia*	2456	S	17	–	5	14	16	1	25	8	1	9	96

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	3 Habitat group F	G	H	I	J	4 Total sites
Senna artemisioides subsp. *helmsii*		S	11	5	2	1	–	–	2	1	–	–	22
Senna artemisioides subsp. *petiolaris*	3694	S	12	9	13	14	–	–	13	2	–	–	63
Senna artemisioides subsp. *sturtii*	3531	S	18	9	6	4	–	–	8	1	–	2	48
Senna artemisioides subsp. *symonii*	3273	S	1	–	–	1	–	–	–	–	–	–	2
Senna cardiosperma subsp. *cardiosperma*	3758	S	–	–	–	–	–	–	–	–	–	–	–
Senna cardiosperma subsp. *manicula*	3718	LS	2	1	–	–	–	–	–	1	–	–	4
Senna glutinosa subsp. *charlesiana*		S	8	9	2	13	–	–	27	5	–	9	73
Senna glutinosa subsp. *chatelainiana*	3515	S	15	7	3	14	1	–	20	3	1	1	65
Senna pleurocarpa	2166	S	–	–	–	–	–	–	–	–	–	–	–
Casuarinaceae													
Allocasuarina acutivalvis	3004	TS	8	–	–	–	–	–	1	2	–	7	18
Allocasuarina campestris	3838	S	3	–	–	1	–	–	–	–	1	4	9
Allocasuarina corniculata	3394	S	–	–	–	–	–	–	–	–	–	4	4
Allocasuarina eriochlamys subsp. *eriochlamys*	3159	T	–	–	–	–	–	–	–	–	–	–	–
Allocasuarina helmsii	30252	TS	–	–	–	–	–	–	–	–	1	–	1
Allocasuarina tessellata	30228	S	1	–	–	–	–	–	–	–	–	–	1
Casuarina obesa	7064	T	2	–	–	–	1	–	2	–	–	–	5
Casuarina pauper	3540	T	10	–	–	1	8	–	–	–	–	1	20
Celastraceae													
Psammomoya choretroides	3766	LS	–	–	–	–	–	–	–	–	–	1	1
Chenopodiaceae													
Atriplex amnicola	2302	S	–	–	–	9	–	4	–	–	–	–	13
Atriplex bunburyana	3248	S	2	1	12	61	5	3	14	1	–	–	99
Atriplex nummularia	7041	S	–	–	–	11	–	–	–	3	–	–	14
Atriplex stipitata	30082	S	–	–	4	27	3	–	–	6	–	–	40
Atriplex vesicaria	2069	LS	1	–	9	50	1	–	1	1	1	1	65
Chenopodium curvispicatum	7005	LS	–	–	–	1	–	–	–	–	–	–	1
Chenopodium gaudichaudianum	3247	LS	2	1	2	19	4	3	4	1	–	–	36
Didymanthus roei	3815	LS	–	–	–	3	–	–	–	–	–	–	3
Enchylaena tomentosa	3798	LS	20	9	16	74	10	7	27	26	2	7	198
Halosarcia doleiformis	3652	LS	–	–	–	–	1	–	–	–	–	–	1
Halosarcia halocnemoides	3534	LS	–	–	3	7	1	–	–	–	–	–	11
Halosarcia halocnemoides subsp. *catenulata*	3037	LS	–	–	–	–	–	–	–	–	–	–	–
Halosarcia indica subsp. *bidens*	3535	LS	–	–	–	–	–	–	–	–	–	–	–
Halosarcia pterygosperma	3274	LS	–	–	–	1	–	–	–	–	–	–	1
Halosarcia undulata	3270	LS	–	–	–	1	–	–	–	–	–	–	1
Maireana amoena	2035	LS	–	–	–	7	–	–	–	–	–	–	7
Maireana appressa	3911	LS	–	–	–	–	–	–	–	–	–	–	–
Maireana atkinsiana	2068	LS	–	–	2	11	–	–	–	–	–	–	13
Maireana convexa	7304	LS	20	9	2	9	1	–	50	16	–	6	113
Maireana georgei	2018	LS	20	3	30	83	7	–	16	21	–	4	184
Maireana glomerifolia	3028	LS	1	1	19	24	–	–	2	–	–	–	47
Maireana melanocoma	3705	LS	–	–	–	–	–	–	–	–	–	–	–
Maireana oppositifolia	30003	LS	–	–	–	–	–	–	–	–	–	–	–
Maireana pentatropis	3506	LS	–	–	–	2	5	–	–	–	–	–	7
Maireana planifolia	2062	LS	10	9	–	2	–	–	18	7	–	3	49
Maireana planifolia x villosa	2029	LS	4	2	–	2	–	–	25	10	1	5	49
Maireana platycarpa	2070	LS	–	–	4	12	–	–	–	–	–	–	16
Maireana pyramidata	6864	S	1	4	28	99	6	2	18	2	–	1	161
Maireana sedifolia		S	–	–	–	–	–	–	–	–	–	–	–
Maireana suaedifolia	7191	S	–	1	–	6	2	–	8	1	–	1	19
Maireana thesioides	2047	LS	12	8	4	20	6	1	40	16	1	7	115
Maireana tomentosa	3276	LS	2	–	13	22	–	–	3	–	–	2	42
Maireana trichoptera	3797	LS	4	2	8	15	5	–	4	6	–	–	44
Maireana triptera	2017	LS	13	8	33	80	8	–	21	9	–	–	172
Maireana villosa	2074	LS	5	6	3	1	–	2	32	15	1	12	77
Rhagodia drummondii	6852	LS	5	1	7	54	11	1	8	21	1	6	115
Rhagodia eremaea	6801	S	36	29	26	66	16	8	105	40	3	14	343
Rhagodia preissii	3131	S	–	–	–	7	2	1	1	2	1	–	14
Sclerolaena diacantha	3544	LS	–	–	–	5	1	–	–	–	–	–	6
Sclerolaena divaricata	2020	LS	–	–	–	–	–	–	–	–	–	1	1
Sclerolaena eurotioides	3663	LS	–	–	1	2	–	–	–	–	–	–	3
Sclerolaena uniflora		LS	–	–	–	2	–	–	–	–	–	–	2

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Sclerostegia disarticulata	2546	LS	–	–	–	2	–	–	–	–	–	–	2
Tecticornia verrucosa	30046	LS	–	–	–	–	–	–	–	–	–	–	–
Chloanthaceae													
Cyanostegia angustifolia	3012	LS	–	–	–	–	–	–	–	–	–	2	2
Dicrastylis brunnea var. *brunnea*	3114	LS	–	–	–	–	–	–	–	–	–	–	–
Dicrastylis exsuccosa	3729	LS	–	–	–	–	–	–	–	–	1	–	1
Dicrastylis linearifolia	3501	S	–	–	–	–	–	–	–	–	–	–	–
Dicrastylis parviflora	30234	LS	–	–	–	–	–	–	–	–	–	–	–
Hemiphora elderi	3739	LS	–	–	–	–	–	–	–	–	–	–	–
Mallophora rugosifolia	3406	LS	–	–	–	–	–	–	–	–	–	–	–
Newcastelia hexarrhena	3454	S	–	–	–	–	–	–	–	–	–	2	2
Newcastelia viscida	30200	LS	–	–	–	–	–	–	–	–	–	–	–
Pityrodia canaliculata	3668	S	–	–	–	–	–	–	–	–	–	–	–
Pityrodia lepidota	3907	S	–	–	–	–	–	–	–	–	–	–	–
Pityrodia terminalis	3008	LS	–	–	–	–	–	–	–	–	–	1	1
Spartothamnella puberula	3707	S	–	–	–	–	–	1	3	1	–	1	6
Spartothamnella teucriiflora	3529	LS	6	11	2	4	–	2	55	6	–	4	90
Convolvulaceae													
Bonamia rosea	2576	LS	–	–	–	–	–	–	–	–	–	1	1
Ipomoea aff. *calobra*	3566	V	–	–	–	–	–	–	2	–	–	–	2
Porana commixta	7253	V	1	1	–	1	–	2	3	–	–	–	8
Porana sericea		V	2	–	1	1	1	1	4	–	–	–	10
Cupressaceae													
Callitris glaucophylla	30083	T	4	–	–	3	2	–	3	25	1	19	57
Callitris preissii	2337	T	–	–	–	–	–	–	1	1	1	2	5
Cyperaceae													
Chrysitrix distigmatosa	3565	G	–	–	–	–	–	–	–	–	1	–	1
Cyperus congestus	3365	G	–	–	–	–	–	–	1	–	–	–	1
Cyperus gymnocaulos	3364	G	–	–	–	–	–	–	1	–	–	–	1
Lepidosperma drummondii	7466	G	–	–	–	–	–	–	–	–	–	–	–
Lepidosperma aff. *effusum*	30237	G	1	–	–	–	–	–	–	–	–	–	1
Lepidosperma aff. *gracile*	3605	G	1	–	–	–	–	–	–	–	–	–	1
Schoenus sp.	3725	G	–	–	–	–	–	–	–	–	1	–	1
Dasypogonaceae													
Chamaexeros macranthera	3636	G	–	–	–	–	–	–	–	–	–	3	3
Lomandra effusa	3799	G	–	–	–	1	–	–	–	1	–	1	3
Lomandra leucocephala subsp. *robusta*	6888	G	–	–	–	–	–	–	–	–	–	1	1
Xerolirion acanthocarpioides		G	–	–	–	–	–	–	–	–	–	–	–
Xerolirion divaricata	3353	G	3	–	–	–	–	–	–	–	–	–	3
Dilleniaceae													
Hibbertia enervia	3380	LS	1	–	–	–	–	–	–	–	–	2	3
Hibbertia exasperata	3616	LS	1	–	–	–	–	–	1	1	–	5	8
Hibbertia glomerosa	3007	LS	–	1	–	–	–	–	–	–	–	–	1
Hibbertia aff. *stricta*	3613	LS	–	–	–	–	–	–	–	–	–	–	–
Hibbertia uncinata	3489	LS	–	–	–	–	–	–	–	–	1	1	2
Epacridaceae													
Astroloma serratifolium	3318	LS	4	1	–	–	–	–	–	–	–	2	7
Epacridaceae gen. nova	3409	LS	–	–	–	–	–	–	–	–	1	3	4
Leucopogon aff. *conostephioides*	3156	LS	2	–	–	–	–	–	–	–	–	–	2
Leucopogon breviflorus	3358	LS	1	–	–	–	–	–	–	–	–	–	1
Euphorbiaceae													
Calycopeplus ephedroides	3204	S	5	7	–	–	–	–	1	–	–	3	16
Pseudanthus 'intricatus' MS	3458	S	–	–	–	–	–	–	–	–	–	–	–
Ricinocarpos velutinus	3282	S	–	–	–	–	–	–	–	–	–	–	–
Sauropus rigens	3973	LS	1	–	–	–	–	–	–	–	–	–	1
Frankeniaceae													
Frankenia cordata	3271	LS	–	–	–	1	–	–	–	–	–	–	1
Frankenia fecunda	3268	LS	–	–	–	2	–	–	–	–	–	–	2
Frankenia laxiflora	3343	LS	–	–	–	1	–	–	–	–	–	–	1
Frankenia magnifica	3993	LS	–	–	–	–	–	–	–	–	–	–	–
Frankenia pauciflora	3201	LS	–	–	1	1	–	–	–	–	–	–	2
Frankenia setosa	3284	LS	–	–	1	3	–	–	1	–	–	–	5
Goodeniaceae													
Dampiera haematotricha subsp. *dura*	3829	LS	–	–	–	–	–	–	–	–	–	1	1

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Dampiera lavandulacea	3803	LS	–	–	–	–	–	–	–	–	–	–	–
Dampiera roycei	3873	LS	–	–	–	–	–	–	–	1	–	–	1
Dampiera stenostachya	7487	LS	–	–	–	–	–	–	–	–	–	–	–
Dampiera tenuicaulis var. *curvula*	3957	LS	–	–	–	–	–	–	–	–	–	–	–
Goodenia helmsii	30161	LS	–	–	–	–	–	–	–	–	–	–	–
Goodenia mueckeana	3074	LS	–	–	–	–	–	–	–	–	–	1	1
Lechenaultia macrantha	3794	LS	–	–	–	–	–	–	–	–	–	–	–
Scaevola restiacea subsp. *restiacea*	3139	LS	–	–	–	–	–	–	–	–	–	–	–
Scaevola spinescens		S	51	6	17	60	12	10	57	26	3	7	249
Gyrostemonaceae													
Codonocarpus cotinifolius	30242	T	–	–	–	1	–	–	–	–	–	–	1
Gyrostemon ramulosus	6828	TS	–	–	–	–	–	–	–	–	–	1	1
Haloragaceae													
Glischrocaryon aureum	3830	LS	–	–	–	–	–	–	–	–	–	1	1
Juncaceae													
Juncus aridicola	2723	G	–	–	–	–	–	–	3	–	–	–	3
Lamiaceae													
Hemigenia brachyphylla	3218	LS	–	–	–	–	–	–	1	–	–	2	3
Hemigenia divaricata	3009	LS	4	–	–	–	–	–	1	–	–	4	9
Hemigenia eutaxioides	3011	LS	–	1	–	–	–	–	–	–	–	–	1
Hemigenia macphersonii	3185	S	3	–	–	–	–	–	–	–	–	–	3
Hemigenia pedunculata	3161	LS	–	–	–	–	–	–	–	–	–	–	–
Hemigenia saligna	3382	LS	–	–	–	–	–	–	–	–	–	–	–
Hemigenia aff. *tysonii*	3211	LS	–	–	–	–	–	–	–	–	–	–	–
Hemigenia westringioides	2235	S	1	–	–	–	–	–	–	2	1	1	5
Hemigenia sp. nova	3809	LS	–	–	–	–	–	–	–	–	–	–	–
Hemigenia sp. nova	3579	LS	–	–	–	–	–	–	–	–	–	–	–
Microcorys tenuifolia	3994	S	–	–	–	–	–	–	1	–	–	–	1
Prostanthera althoferi	3050	S	8	1	–	–	–	–	9	2	1	12	33
Prostanthera althoferi subsp. *althoferi*	3217	S	–	–	–	–	–	–	–	–	–	–	–
Prostanthera baxteri	3298	LS	–	–	–	–	–	–	–	–	–	2	2
Prostanthera campbelii	3478	LS	–	–	–	–	–	–	–	–	–	–	–
Prostanthera canaliculatum	30063	LS	–	–	–	–	–	–	–	2	–	2	4
Prostanthera grylloana	2213	S	–	–	–	–	–	–	–	1	–	2	3
Prostanthera magnifica	3145	S	3	–	–	–	–	–	–	–	–	–	3
Prostanthera patens	3796	LS	1	–	–	–	–	–	–	–	–	2	3
Prostanthera semiteres	3039	S	3	–	–	–	–	–	1	–	–	2	6
Prostanthera serpyllifolia	30220	LS	5	–	–	–	–	–	–	1	–	–	6
Prostanthera serpyllifolia subsp. *microphylla*	3151	LS	1	–	–	–	–	–	–	–	–	1	2
Prostanthera striatiflora	3058	LS	1	–	–	–	–	–	–	–	–	–	1
Prostanthera aff. *tysonii*	3190	LS	–	–	–	–	–	–	1	–	–	–	1
Prostanthera wilkieana	2670	LS	2	–	–	–	–	–	1	2	–	3	8
Prostathera eckersleyana	30060	LS	–	–	–	–	–	–	–	–	–	1	1
Westringia cephalantha	3377	LS	1	–	–	–	–	–	–	2	1	1	4
Westringia rigida	30264	LS	–	–	–	–	–	–	–	–	2	–	2
Wrixonia prostantheroides	3666	LS	–	–	–	–	–	–	–	1	–	–	1
Lauraceae													
Cassytha nodiflora	30219	P	1	–	–	–	–	–	–	–	–	–	1
Loranthaceae													
Amyema gibberulum var. *gibberulum*	30205	P	–	–	–	–	–	–	–	–	–	–	–
Amyema gibberulum var. *tatei*	2608	P	–	–	–	–	–	–	–	–	–	–	–
Amyema nestor	6914	P	2	1	–	–	–	–	1	–	–	–	4
Lysiana casuarinae	3527	P	–	–	–	3	–	2	2	2	–	–	9
Lysiana murrayi	6813	P	–	–	–	–	–	2	2	–	–	–	4
Malvaceae													
Abutilon cryptopetalum	7277	LS	1	–	–	–	–	–	1	–	–	–	2
Abutilon oxycarpum	7526	LS	–	1	–	–	–	–	–	–	–	–	1
Abutilon sp.	3367	H	–	–	–	–	–	–	–	–	–	–	–
Alyogyne pinoniana	3473	LS	–	–	–	–	–	–	–	–	3	1	4
Hibiscus sturtii	3683	S	–	–	–	–	–	–	–	–	–	–	–
Lawrencia helmsii	6905	LS	–	–	–	1	3	–	–	–	–	–	4
Lawrencia squamata	3283	LS	–	–	1	2	–	–	–	–	–	–	3
Radyera farragei	3591	S	–	–	–	–	–	–	–	–	–	–	–
Sida calyxhymenia	3052	S	34	24	11	11	3	–	53	5	–	4	145
Sida corrugata		LS	2	1	1	–	–	–	–	–	–	–	4

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	F 3 Habitat group	G	H	I	J	4 Total sites
Sida corrugata var. *ovata*	3187	LS	–	–	–	–	–	–	–	1	–	–	1
Sida sp. nova 'dark green fruits'	30270	LS	–	–	–	–	–	–	–	–	–	–	–
Sida filiformis	3722	LS	6	2	–	1	–	–	1	1	–	1	12
Sida virgata	3194	LS	2	–	–	–	–	–	–	–	–	–	2
Mimosaceae													
Acacia acuaria	30048	S	–	–	–	–	–	–	–	–	–	–	–
Acacia 'acuminata subsp. *acuminata'* MS	3559	S	2	4	1	2	–	–	2	10	1	10	32
Acacia 'acuminata subsp. *burkittii'* MS	3569	S	63	32	18	50	19	7	83	35	2	19	328
Acacia aff. *alata* var. *biglandulosa*	3839	S	–	–	–	–	–	–	–	–	–	–	–
Acacia andrewsii	3278	S	4	1	3	3	–	–	–	1	–	4	16
Acacia aneura	3610	TS	58	31	13	40	9	10	148	34	14	35	392
Acacia aulaocaphylla	3390	S	–	–	–	–	–	–	–	–	–	–	–
Acacia colletioides	6849	LS	2	3	–	8	2	–	–	23	7	8	53
Acacia coolgardiensis	6735	TS	2	–	–	–	–	–	7	8	12	32	61
Acacia coolgardiensis subsp. *coolgardiensis*	3288	TS	–	–	–	–	–	–	–	–	–	3	3
Acacia coolgardiensis subsp. *effusa*	3619	TS	–	–	–	–	–	–	–	–	–	3	3
Acacia aff. *coolgardiensis*	3984	TS	2	–	–	–	–	–	2	1	–	5	10
Acacia craspedocarpa	2592	TS	6	15	5	7	–	1	54	3	1	3	95
Acacia donaldsonii	3045	S	2	–	–	2	–	–	1	–	–	–	5
Acacia duriuscula	2318	TS	–	–	–	–	–	–	–	–	–	1	1
Acacia eremaea		TS	–	–	2	16	–	–	5	–	–	–	23
Acacia eremophila var. *eremophila*	3737	TS	–	1	–	1	–	–	–	–	–	–	2
Acacia erinacea	3638	LS	9	–	2	5	–	–	1	3	–	–	20
Acacia exocarpoides	3262	S	5	2	1	–	–	–	9	1	–	2	20
Acacia grasbyi		TS	11	8	1	9	2	1	41	1	1	3	78
Acacia hemiteles	3304	S	–	–	–	3	–	–	–	6	–	2	11
Acacia heteroneura var. *jutsonii*	2095	S	–	–	–	–	–	–	–	–	–	1	1
Acacia heteroneura var. *prolixa*	3740	TS	–	–	–	–	–	–	–	–	–	1	1
Acacia inceana subsp. *conformis*	3965	S	–	–	–	–	–	–	–	–	–	–	–
Acacia irritans	3859	LS	–	–	–	–	–	–	–	–	–	–	–
Acacia jamesiana	3563	S	–	–	–	–	–	–	–	–	–	1	1
Acacia jennerae	3867	TS	–	–	–	3	–	–	–	2	1	–	6
Acacia jibberdingensis	3602	S	2	–	–	–	–	–	–	–	–	–	2
Acacia 'kalgoorliensis' MS	3034	S	1	–	1	2	1	–	1	–	–	2	8
Acacia kochii	3841	LS	1	–	–	–	–	–	–	–	–	–	1
Acacia aff. *leptopetala*	3128	S	–	–	–	–	–	–	–	–	–	–	–
Acacia ligulata	3690	S	1	–	–	–	2	–	–	–	1	1	5
Acacia lineolata subsp. *lineolata*	30112	TS	–	–	–	1	–	–	–	–	–	–	1
Acacia linophylla	6948	TS	1	–	–	1	–	2	8	1	–	–	13
Acacia longispinea	3171	S	–	–	–	–	–	–	1	–	–	2	3
Acacia mackeyana	3427	TS	–	–	–	–	–	–	–	–	–	–	–
Acacia masliniana	3272	TS	–	–	1	17	1	–	1	–	–	–	20
Acacia merrallii	30241	TS	–	–	–	1	–	–	–	–	–	–	1
Acacia microcalyx	3206	S	1	–	1	8	–	–	2	1	–	–	13
Acacia murrayana	3216	TS	–	–	–	–	–	–	–	–	–	–	–
Acacia neurocarpa	30128	S	–	–	–	–	–	–	–	–	–	1	1
Acacia nyssophylla	2031	LS	–	–	–	–	–	–	–	1	–	–	1
Acacia oswaldii	3072	TS	–	–	1	3	–	–	–	–	–	–	4
Acacia pachycarpa	6844	S	–	–	–	1	–	–	–	1	1	–	3
Acacia palustris	3600	TS	–	–	–	–	–	–	–	–	–	–	–
Acacia papyrocarpa	2189	T	–	–	1	–	–	–	–	–	–	–	1
Acacia prainii	3849	S	–	–	–	–	–	–	–	2	1	1	4
Acacia pruinocarpa	2705	T	2	2	–	–	1	–	3	1	–	–	9
Acacia quadrimarginea	3153	TS	61	44	4	–	–	–	10	1	–	6	126
Acacia ramulosa	3047	TS	51	25	6	26	5	1	126	49	6	40	335
Acacia resinomarginea	3411	TS	–	1	–	–	–	–	1	–	2	1	5
Acacia resinosa	30236	TS	1	–	–	–	–	–	–	–	–	1	2
Acacia restiacea	3604	LS	1	–	–	–	–	–	–	–	–	–	1
Acacia rhodophloia	3329	TS	2	2	–	–	–	–	–	–	–	1	5
Acacia roycei	30049	TS	–	–	–	–	–	–	–	1	–	–	1
Acacia aff. *sabserrilis*	3243	S	2	–	–	–	–	–	–	–	–	–	2
Acacia scleroclada	3587	LS	1	–	–	–	–	–	–	–	–	–	1
Acacia sclerosperma	3592	TS	–	–	–	–	3	2	6	1	–	–	12
Acacia sclerosperma subsp. *sclerosperma*	3785	TS	–	–	–	–	–	–	–	–	–	–	–
Acacia sibina	3172	S	1	–	–	–	–	–	–	–	–	6	7
Acacia sibulans	3205	T	–	–	–	4	–	–	–	–	–	–	4
Acacia speckii	3339	TS	1	1	–	1	–	–	–	–	–	–	3
Acacia steedmanii	3418	S	1	–	–	–	–	–	–	–	–	2	3
Acacia stereophylla	3412	S	–	–	–	–	–	–	–	–	–	3	3
Acacia subrigida	3847	TS	–	–	–	–	–	–	–	–	–	–	–
Acacia tetragonophylla	7280	TS	75	47	18	85	17	17	164	39	7	28	497

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	3 Habitat group F	G	H	I	J	4 Total sites
Acacia tysonii	3231	S	1	1	–	9	4	1	8	–	–	–	24
Acacia victoriae	6802	TS	1	–	–	11	6	2	5	1	–	–	26
Acacia xanthocarpa	3541	TS	3	1	–	–	–	–	–	–	–	–	4
Acacia yorkrakinensis	3400	TS	–	–	–	–	–	–	–	–	–	–	–
Myoporaceae													
Eremophila alternifolia	3695	S	3	–	1	1	2	–	6	1	–	–	14
Eremophila caperata	30130	TS	–	–	–	–	–	–	–	1	–	–	1
Eremophila clarkei	3003	LS	19	7	1	4	–	1	31	14	3	18	98
Eremophila aff. *clarkei*	3260	LS	2	–	1	1	–	–	1	–	–	–	5
Eremophila compacta	3714	LS	9	6	2	2	–	1	10	1	–	–	31
Eremophila decipiens	3768	S	1	–	2	15	1	–	5	14	4	5	47
Eremophila drummondii	3862	S	–	–	–	1	–	–	–	–	–	–	1
Eremophila eriocalyx	3049	S	7	9	–	6	2	2	32	12	2	15	87
Eremophila exilifolia	3099	LS	13	5	1	–	–	–	–	–	–	–	19
Eremophila aff. *exotrachys*	3954	LS	1	–	–	1	–	–	–	–	–	–	2
Eremophila falcata	30185	S	–	–	–	–	–	–	2	1	–	–	3
Eremophila flabulata	3097	S	4	1	–	–	–	–	2	–	–	–	7
Eremophila foliosissima	3661	LS	–	–	–	–	–	–	5	–	–	–	5
Eremophila forrestii	3577	S	38	31	3	13	–	2	63	22	5	32	209
Eremophila forrestii subsp. *hastieana*	3711	S	–	–	–	–	–	–	–	–	–	–	–
Eremophila forrestii x latrobei	3551	LS	–	–	–	–	–	–	–	–	–	–	–
Eremophila fraseri	6910	S	9	7	1	2	1	–	22	–	–	–	42
Eremophila georgei	3089	LS	15	4	2	2	2	–	22	8	1	13	69
Eremophila aff. *georgei*	3197	LS	–	1	–	–	–	–	–	1	–	–	2
Eremophila gilesii	2269	LS	1	–	–	–	–	–	2	1	–	–	4
Eremophila glabra	3129	LS	–	–	–	6	–	3	–	2	2	–	13
Eremophila glandulifera	3118	LS	1	1	–	–	–	–	1	–	–	–	3
Eremophila glutinosa	3238	S	3	–	–	–	–	–	–	–	–	–	3
Eremophila granitica	3340	S	1	1	–	3	–	–	7	2	3	7	24
Eremophila aff.granitica	3878	TS	–	–	–	–	–	–	–	–	–	–	–
Eremophila homoplastica	2112	LS	–	–	–	–	–	–	1	–	–	–	1
Eremophila hygrophana	3226	LS	–	–	–	–	–	–	1	–	–	–	1
Eremophila interstans subsp. *virgata*	2219	S	–	–	–	–	–	–	–	1	–	–	1
Eremophila ionantha	3375	S	–	–	–	4	–	–	–	1	–	–	5
Eremophila jacunda	3880	LS	–	2	–	–	–	–	–	–	–	–	2
Eremophila lachnocalyx	3027	S	–	3	6	3	–	–	3	1	–	–	16
Eremophila latrobei	3006	S	52	22	5	4	1	–	44	3	–	19	150
Eremophila longifolia	2078	T	2	4	4	16	5	11	18	3	–	–	63
Eremophila macmillaniana	2049	TS	–	3	–	1	–	–	1	–	–	–	5
Eremophila maculata	2111	LS	–	–	–	21	–	2	1	–	–	–	24
Eremophila 'malacoides' MS	3208	LS	–	–	–	4	–	–	1	–	–	–	5
Eremophila metallicorum	3905	LS	3	4	–	1	–	–	9	1	–	–	18
Eremophila miniata	30026	TS	–	–	–	16	–	–	3	1	–	–	20
Eremophila oldfieldii	3176	S	10	1	10	8	2	1	–	1	–	–	33
Eremophila oldfieldii subsp. *angustifolia*	3572	TS	11	2	4	3	–	1	4	1	–	–	26
Eremophila oppositifolia	3580	TS	10	1	12	11	2	–	1	4	–	–	41
Eremophila pachyphylla	3403	TS	–	–	–	–	–	–	–	5	3	–	8
Eremophila pantonii	2550	S	–	1	3	3	1	–	1	–	–	–	9
Eremophila platycalyx	3267	TS	11	17	4	–	–	–	6	–	–	–	38
Eremophila platythamnos	3133	LS	–	–	–	–	–	–	–	–	–	1	1
Eremophila punctata	3686	LS	2	–	–	–	–	–	–	–	–	–	2
Eremophila pungens	6767	S	1	–	–	–	–	–	–	–	–	–	1
Eremophila punicea		LS	–	3	2	2	–	–	12	–	–	2	21
Eremophila scoparia	3076	S	4	–	4	27	4	–	7	4	1	–	51
Eremophila serrulata	3585	S	4	1	–	6	1	–	11	–	–	–	23
Eremophila simulans	3641	LS	–	–	–	–	–	–	–	–	–	–	–
Eremophila aff. *spectabilis*	3232	S	–	–	–	–	–	–	–	–	–	–	–
Eremophila youngii subsp. *youngii*	6960	TS	3	–	3	6	1	–	2	–	–	–	15
Myoporum deserti	3861	S	–	–	–	1	–	–	–	–	–	–	1
Myrtaceae													
Baeckea aff. *baileyana*	3413	LS	–	–	–	–	–	–	–	–	1	1	2
Baeckea cryptandroides	3116	LS	–	–	–	–	–	–	–	–	–	2	2
Baeckea elderiana	7386	LS	–	–	–	–	–	–	–	–	–	5	5
Baeckea maidenii	3787	LS	–	–	–	–	–	–	–	–	–	–	–
Baeckea pentagonantha	3310	LS	1	–	–	–	–	–	–	–	–	–	1
Baeckea sp. *nova*	3715	LS	–	–	–	–	–	–	–	–	–	–	–
Baeckea uncinella	30110	S	2	–	–	–	–	–	–	–	–	2	2
Balaustion microphyllum	3280	LS	–	–	–	–	–	–	–	–	–	–	–
Callistemon phoeniceus	3143	TS	–	–	–	–	–	–	6	–	–	–	6
Calothamnus aridus	3710	S	–	–	–	–	–	–	–	–	–	1	1
Calothamnus gilesii	6781	S	1	–	–	–	–	–	–	–	–	–	1

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	F	G	H	I	J	4 Total sites
								3 Habitat group					
Calothamnus superbus	3137	TS	–	–	–	–	–	–	–	–	1	–	1
Calytrix amethystina	3046	LS	–	–	–	–	–	–	–	–	–	–	–
Calytrix creswellii	3401	LS	–	–	–	–	–	–	–	–	–	–	–
Calytrix desolata	3055	LS	3	–	–	–	–	–	–	–	–	–	3
Calytris aff. *divergens*	30094	LS	1	–	–	–	–	–	–	–	–	–	1
Calytrix strigosa	3925	LS	–	–	–	–	–	–	–	–	–	–	–
Calytrix verruculosa	3344	LS	1	–	–	–	–	–	–	–	–	–	1
Chamelaucium sp.	3524	TS	–	–	–	–	–	–	–	–	–	–	–
Darwinia aff. *diosmoides*	3281	LS	–	–	–	–	–	–	–	–	–	1	1
Darwinia sp. nova	3346	LS	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus brachycorys	3510	M	–	–	–	–	–	–	–	–	1	–	1
Eucalyptus aff. brockwayi	3852	M	–	–	–	–	–	–	–	–	–	1	1
Eucalyptus aff. *camaldulensis*	3937	T	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus capillosa subsp. *capillosa*	3155	T	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus carnei	3115	T/M	1	–	–	–	–	–	–	–	–	–	1
Eucalyptus celastroides	3334	M	–	–	–	–	–	–	–	1	–	–	1
Eucalyptus clelandii	3313	T/M	2	–	–	1	–	–	–	–	–	–	3
Eucalyptus concinna	3988	M	2	–	–	1	1	–	–	1	1	–	6
Eucalyptus corrugata	3164	M	–	–	–	1	–	–	–	–	–	–	1
Eucalyptus crucis subsp. *lanceolata*	3927	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus aff. *cylindrocarpa*	3906	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus aff. *cylindroidea*	30239	M	–	–	–	1	–	–	1	–	2	–	4
Eucalyptus ebbanoensis	30212	M	2	–	–	–	–	–	–	–	–	–	2
Eucalyptus effusa subsp. aff. *exsul*	3233	M	–	–	–	–	1	–	–	–	–	–	1
Eucalyptus ewartiana	3040	M	1	–	–	–	–	–	6	4	–	9	20
Eucalyptus formanii	3431	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus glomerosa	3395	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus gongylocarpa	3042	T	–	–	–	–	–	–	–	–	5	1	6
Eucalyptus gracilis	3609	M	–	–	–	–	–	–	–	–	–	1	1
Eucalyptus aff. *griffithsii*	30248	T	–	–	–	1	–	–	–	–	–	–	1
Eucalyptus hypochlamydea subsp. *ecdysiastes*	30067	T	–	–	–	–	–	–	–	1	–	–	1
Eucalyptus hypochlamydea subsp. *hypochlamydea*	3874	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus kingsmillii	6734	M	1	–	–	–	–	–	1	–	6	–	8
Eucalyptus kochii	3048	M		–	–	–	–	–	–	–	1	1	2
Eucalyptus kochii subsp. *kochii*	3451	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus kochii subsp. *plenissima*	3421	M	–	–	–	–	–	–	–	1	1	1	3
Eucalyptus leptophylla	3487	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus leptopoda	3608	M	–	–	–	–	–	–	2	–	3	13	18
Eucalyptus lesouefii	6806	T/M	–	–	–	1	–	–	–	–	–	–	1
Eucalyptus longicornis	3655	T	–	–	–	–	–	–	–	2	1	4	7
Eucalyptus loxophleba		M	6	–	3	17	–	1	1	22	–	6	56
Eucalyptus loxophleba subsp. *lissophloia*	3381	M	–	–	–	1	–	–	–	–	–	–	1
Eucalyptus loxophleba subsp. *supralaevis*	30115	T	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus lucasii	3657	M	–	–	–	–	–	–	2	2	1	–	5
Eucalyptus melanoxylon	3952	T/M	–	–	–	–	–	–	–	–	1	–	1
Eucalyptus oldfieldii	3479	M	–	–	–	–	–	–	–	1	1	2	4
Eucalyptus oleosa	3196	M	–	–	–	2	–	–	1	3	1	–	7
Eucalyptus oleosa var. *oleosa*	3888	M	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus orbifolia	3505	M	1	–	–	–	–	–	–	–	–	–	1
Eucalyptus rigidula	3396	M	–	–	–	–	–	–	–	–	–	1	1
Eucalyptus salicola	3168	T	–	–	–	1	–	–	–	–	–	–	1
Eucalyptus salmonophloia		T	–	–	–	4	–	–	–	–	–	–	4
Eucalyptus salubris var. *salubris*	3384	T/M	–	–	1	12	–	–	–	2	–	–	15
Eucalyptus striaticalyx	30002	T	–	–	–	–	5	–	–	–	–	–	5
Eucalyptus stricklandii	2179	T	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus transcontinentalis	3402	T/M	–	–	–	–	–	–	–	3	–	–	3
Eucalyptus trichopoda	30190	T/M	1	–	–	1	–	–	1	2	–	–	5
Eucalyptus yilgarnensis	3162	M	–	–	–	–	–	–	–	–	2	–	2
Homalocalyx thryptomenoides	30075	LS	–	–	–	–	–	–	–	–	–	6	6
Kunzea pulchella	7456	TS	2	–	–	–	–	–	–	–	–	–	2
Leptospermum erubescens	3404	S	–	–	–	–	–	–	–	–	–	–	–
Malleostemon roseus	3113	S	–	–	–	–	–	–	–	–	–	–	–
Malleostemon tuberculatus	3140	S	1	1	–	–	–	–	–	2	–	6	10
Melaleuca aff. *conothamnoides*	3399	S	–	–	–	–	–	–	–	–	–	–	–
Melaleuca aff. *lateriflora* subsp. *acutifolia*	30080	TS	–	–	–	–	–	1	–	–	–	1	2
Melaleuca cordata	3826	S	–	–	–	–	–	–	–	–	–	7	7
Melaleuca eleuterostachya	3301	S	2	–	–	2	–	3	2	1	1	10	21
Melaleuca filifolia	3294	TS	2	–	–	–	–	–	–	–	–	1	3
Melaleuca glomerata	30066	TS	–	–	–	–	–	–	–	1	–	–	1
Melaleuca lateriflora	3303	TS	–	–	1	–	–	1	–	–	–	1	2
Melaleuca leiocarpa	3319	TS	4	–	–	–	–	1	2	1	–	7	15

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	3 Habitat group E	F	G	H	I	J	4 Total sites
Melaleuca oldfieldii	3958	LS	–	–	–	–	–	–	–	–	–	1	1
Melaleuca radula	3222	S	1	1	–	–	–	–	–	–	–	–	2
Melaleuca sheathiana	6799	TS	–	–	–	2	1	4	–	–	–	–	7
Melaleuca thyoides	3753	TS	–	–	–	–	–	–	–	–	–	–	–
Melaleuca uncinata	3063	TS	7	8	1	2	–	7	4	3	3	18	56
Micromyrtus clavata	3759	S	–	–	–	–	–	–	–	–	–	–	–
Micromyrtus elobata	3611	TS	–	–	–	–	–	–	–	–	–	–	–
Micromyrtus flaviflora	3732	LS	–	–	–	–	–	–	–	–	1	–	1
Micromyrtus obovatus	3762	S	–	–	–	–	–	–	–	–	–	–	–
Micromyrtus racemosa	3309	S	4	–	–	–	–	–	2	–	–	–	6
Micromyrtus racemosa var. *prochytes*	3328	S	1	–	–	–	–	–	–	–	–	–	1
Micromyrtus racemosa var. *racemosa*	3772	LS	–	–	–	–	–	–	–	–	–	–	–
Micromyrtus sulphurea	3111	S	1	–	–	–	–	–	–	–	–	–	1
Thryptomene appressa	3001	LS	–	–	–	–	–	–	–	–	–	–	–
Thryptomene aspera	3942	S	1	–	–	–	–	–	–	–	–	–	1
Thryptomene aspera subsp. *glabra*	3091	LS	2	–	–	–	–	–	–	–	–	8	10
Thryptomene baeckeacea	3761	S	–	–	–	–	–	–	–	–	–	–	–
Thryptomene decussata	3192	S	13	2	–	–	–	–	1	–	–	1	17
Thryptomene kochii	3828	S	–	–	–	–	–	–	–	–	–	1	1
Thryptomene maisonneuvei	3736	S	–	–	–	–	–	–	–	–	–	–	–
Thryptomene mucronulata	3184	S	7	19	–	–	–	–	1	–	–	2	29
Thryptomene strongylophylla	30127	S	1	–	–	–	–	–	–	–	–	1	2
Thryptomene urceolaris	30170	S	–	–	–	–	–	–	–	1	1	–	2
Verticordia helmsii	3389	LS	–	–	–	–	–	–	–	–	–	–	–
Verticordia interioris	3067	LS	1	–	–	–	–	–	–	–	–	–	1
Verticordia rennieana	30201	LS	–	–	–	–	–	–	–	–	–	–	–
Papilionaceae													
Bossiaea concinna	2450	LS	–	–	–	–	1	–	–	1	–	–	2
Bossiaea walkeri	3147	S	–	1	–	5	2	–	1	7	1	1	18
Brachysema aphyllum	3177	LS	1	1	–	–	–	–	–	–	–	–	2
Chorizema genistoides	30014	LS	1	1	–	–	–	–	–	–	–	–	2
Daviesa benthamii	3414	S	–	–	–	–	–	–	–	1	2	–	3
Daviesia grahamii	3881	LS	–	–	–	1	–	–	–	–	–	–	1
Eutaxia microphylla	3637	LS	–	–	–	–	–	–	–	–	–	–	–
Eutaxia sp.	3482	LS	–	–	–	–	–	–	–	–	–	–	–
Gastrolobium laytonii	2763	TS	3	–	–	–	–	–	–	–	–	–	3
Glycine canescens	3567	V	–	–	–	–	–	–	3	–	–	–	3
Indigofera australis	3586	LS	–	–	–	–	–	–	–	–	–	–	–
Indigofera brevidens	3117	LS	–	–	–	–	–	–	–	–	–	–	–
Indigofera georgei	3704	LS	1	1	–	1	–	–	1	–	–	–	4
Jacksonia foliosa	3180	S	–	–	–	1	–	–	–	1	–	–	2
Jacksonia restioides	3622	S	–	–	–	–	–	–	–	–	–	–	–
Kennedia prorepens	3098	V	–	–	–	–	–	–	–	–	2	–	2
Leptosema aculeatum	3733	LS	–	–	–	–	–	–	–	–	–	–	–
Leptosema chambersii	6827	LS	–	–	–	–	–	–	–	–	1	1	2
Mirbelia depressa	3259	LS	1	2	–	–	–	–	–	–	–	2	5
Mirbelia aff. *longifolia*	3135	S	–	–	–	–	–	–	–	–	–	–	–
Mirbelia aff. *microphylla*	3059	S	1	–	–	–	–	–	–	–	–	–	1
Mirbelia rhagodioides	3322	S	6	1	–	–	–	–	1	1	–	2	11
Mirbelia spinosa		S	3	–	–	1	–	–	–	2	–	2	8
Templetonia egena	3817	S	–	–	–	1	–	–	–	–	–	–	1
Templetonia sulcata	3504	S	–	–	–	–	1	–	–	–	1	–	2
Phormiaceae													
Dianella revoluta	7409	G	14	14	–	8	1	2	70	23	7	51	190
Pittosporaceae													
Billardiera bicolor var. *bicolor*	30226	S	–	–	–	–	–	–	–	–	–	–	–
Bursaria occidentalis	3212	TS	2	1	–	1	–	–	3	6	3	3	19
Cheiranthera filifolia	3311	LS	–	–	–	–	–	–	–	–	–	–	–
Pittosporum phylliraeoides	3244	T	1	1	1	7	4	6	3	1	–	–	24
Poaceae													
Amphipogon caricinus	7270	G	3	3	–	2	1	–	9	7	5	26	56
Amphipogon caricinus var. *caricinus*	30015	G	–	–	–	–	–	–	–	–	–	–	–
Amphipogon strictus	3179	G	1	–	–	–	–	–	4	11	1	17	34
Cymbopogon ambiguus	7397	G	5	1	1	–	–	–	–	–	–	–	7
Danthonia caespitosa	3032	G	1	1	–	–	–	–	–	7	–	–	9
Digitaria brownii	3684	G	–	–	–	–	–	–	–	–	–	–	–
Enneapogon caerulescens var. *caerulescens*	3369	G	3	–	1	–	–	–	1	–	–	–	5
Eragrostis australasica	2463	G	–	–	–	1	–	1	–	–	–	–	2

Family Botanical name	1 Collection no.	2 Growth form	3 Habitat group										4 Total sites
			A	B	C	D	E	F	G	H	I	J	
Eragrostis eriopoda	3051	G	2	–	1	1	1	–	15	9	4	6	39
Eragrostis falcata	2807	G	–	–	–	–	–	–	1	–	–	–	1
Eragrostis laniflora	2780	G	–	–	–	–	–	–	1	–	–	–	1
Eragrostis lanipes	3123	G	–	–	–	1	–	–	1	1	1	–	4
Eragrostis parviflora	30000	G	–	–	–	–	–	–	–	–	–	–	–
Eragrostis setifolia	3998	G	–	–	–	5	–	4	2	–	–	1	12
Eragrostis xerophila	3024	G	–	–	–	1	–	–	–	–	–	–	1
Eriachne aristidea	30216	G	2	–	–	–	–	–	–	–	–	–	2
Eriachne flaccida	3023	G	–	–	–	10	–	7	11	–	–	–	28
Eriachne helmsii	6905	G	–	–	–	2	–	–	6	3	2	4	17
Eriachne mucronata	3077	G	–	–	–	–	–	1	–	–	–	–	1
Eriochloa pseudoacrotricha	3360	G	–	–	–	–	–	–	–	–	–	–	–
Monachather paradoxa	2075	G	15	15	–	15	3	–	72	47	11	59	237
Paractaenum novae-hollandiae	3125	G	–	–	–	–	–	–	–	–	–	–	–
Stipa elegantissima	3043	G	31	16	9	70	16	17	92	50	3	44	348
Stipa eremophila	3234	G	–	–	–	–	–	–	–	–	–	–	–
Stipa flavescens	30061	G	–	–	–	–	–	–	–	1	–	–	1
Stipa nitida	3021	G	–	–	–	–	–	–	–	–	–	–	–
Stipa platychaeta	3372	G	–	–	–	1	–	–	–	–	–	–	1
Stipa tuckeri	3757	G	–	–	–	–	–	–	–	–	–	–	–
Themeda triandra	2263	G	2	–	–	–	–	–	–	–	–	–	2
Thyridolepis mitchelliana	2119	G	2	–	–	–	–	–	1	2	–	1	6
Thyridolepis multiculmis	2651	G	2	3	–	–	–	–	2	2	3	11	23
Triodia basedowii	2079	G	–	–	–	3	–	–	5	5	18	4	35
Triodia danthonioides	3625	G	–	–	–	–	–	–	–	–	–	–	–
Triodia desertorum	30143	G	–	–	–	–	–	–	–	2	–	1	3
Triodia longipalea	3289	G	–	–	–	–	–	–	–	–	1	1	2
Triodia melvillei	3706	G	–	–	–	–	–	–	–	2	–	–	2
Triodia rigidissima	3173	G	–	–	–	–	–	–	–	1	4	1	6
Triodia scariosa	30030	G	–	–	–	–	–	–	–	–	–	–	–
Polygalaceae													
Comesperma integerrimum	3157	V	9	6	–	7	1	3	13	7	–	13	59
Muehlenbeckia cunninghamii	30005	S	–	–	–	–	–	4	–	–	–	–	4
Proteaceae													
Banksia elderiana	30174	S	–	–	–	–	–	–	–	–	–	–	–
Dryandra arborea	30098	T	1	–	–	–	–	–	–	–	–	–	1
Grevillea acacioides	3584	S	–	–	–	–	–	–	1	–	1	–	2
Grevillea acuaria	30193	S	–	–	–	–	–	–	1	–	–	–	1
Grevillea berryana	2812	TS	–	–	–	–	1	1	–	–	–	–	2
Grevillea deflexa	2761	S	–	–	–	1	–	–	10	–	–	–	11
Grevillea didymobotrya	3134	TS	–	–	–	–	–	–	–	–	2	1	3
Grevillea erectiloba	3148	S	–	–	–	–	–	–	–	–	–	–	–
Grevillea eriobotrya	3433	TS	–	–	–	–	–	–	–	–	–	–	–
Grevillea eriostachya	3215	TS	–	–	–	–	–	–	–	–	–	1	1
Grevillea extorris	3100	S	1	–	–	1	–	–	1	1	–	–	4
Grevillea georgeana	30101	S	2	–	–	–	–	–	–	–	–	–	2
Grevillea globosa	3333	TS	–	–	–	–	–	–	–	–	–	1	1
Grevillea hakeoides	3782	S	–	–	–	1	1	–	–	–	–	–	2
Grevillea inconspicua	6757	S	2	–	–	–	–	–	–	–	–	–	2
Grevillea integrifolia	3464	S	–	–	–	–	–	–	–	–	1	–	1
Grevillea juncifolia	7147	TS	–	–	–	–	–	–	–	–	–	1	1
Grevillea nana	7583	S	–	–	–	–	–	–	–	–	–	1	1
Grevillea nana subsp. *nana*	3170	LS	–	–	–	–	–	–	–	–	–	–	–
Grevillea aff. *nematophylla*	30198	TS	–	–	–	–	–	–	1	–	–	–	1
Grevillea obliquistigma	3199	TS	9	2	–	1	1	1	7	1	1	17	40
Grevillea paniculata	3802	S	1	2	–	–	–	–	–	–	–	–	3
Grevillea paradoxa	3005	S	1	1	–	–	–	–	1	2	1	4	10
Grevillea petrophiloides	3676	TS	–	–	–	–	–	–	–	–	–	–	–
Grevillea pityophylla	3186	S	3	8	–	–	–	–	2	–	–	4	17
Grevillea pityrodia	3670	S	–	–	–	–	–	–	–	–	–	–	–
Grevillea sarissa	3038	S	–	–	–	1	1	–	1	–	–	–	3
Grevillea scabrida	3856	S	–	–	–	–	–	–	–	–	–	–	–
Grevillea stenobotrya	2113	TS	–	–	–	1	1	–	3	–	–	–	5
Grevillea stenostachya	3327	LS	2	–	–	–	–	–	–	–	–	–	2
Grevillea striata		TS	–	–	–	–	1	1	–	–	–	–	2
Grevillea teretifolia	3592	S	1	1	–	–	–	–	–	–	–	–	2
Hakea arida	3321	TS	5	8	5	7	–	1	19	1	–	1	47
Hakea coriacea	3819	TS	–	–	–	–	–	–	–	–	–	4	4
Hakea francisiana	2003	TS	–	–	–	–	–	–	–	–	1	–	1
Hakea invaginata	3558	LS	–	–	–	–	–	–	–	–	1	4	5
Hakea minyma	3081	TS	–	–	–	–	–	–	–	1	1	1	3
Hakea preissii		TS	5	7	21	39	–	5	8	2	1	1	89
Hakea recurva	2549	TS	20	6	3	5	1	2	45	18	–	24	124
Hakea suberea	6925	T	2	1	–	–	–	1	3	–	–	2	9

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	3 Habitat group F	G	H	I	J	4 Total sites
Hakea subsulcata	30117	TS	–	–	–	–	–	–	–	–	–	–	–
Persoonia aff. *coriacea*	30224	S	–	–	–	–	–	–	–	–	–	–	–
Persoonia sp.	3341	TS	–	–	–	–	–	–	–	–	–	–	–
Petrophile conifera	30093	S	1	–	–	–	–	–	–	–	–	–	1
Petrophile aff. *semifurcata*	3356	S	1	–	–	–	–	–	–	–	–	–	1
Restionaceae													
Ecdeiocolea monostachya	3626	G	–	–	–	–	–	–	–	1	–	4	5
Rhamnaceae													
Cryptandra connata	3178	S	–	–	–	–	–	–	–	–	–	–	–
Cryptandra glabriflora	3823	LS	–	–	–	–	–	–	–	–	–	1	1
Spyridium sp.			1	–	–	–	–	–	–	–	–	–	1
Trymalium sp.	3749	LS	–	–	–	–	–	–	–	–	–	–	–
Rubiaceae													
Canthium attenuatum	2086	TS	–	1	–	1	–	–	2	2	–	–	6
Canthium latifolium		TS	2	–	–	–	–	–	2	–	–	–	4
Canthium lineare	6845	TS	3	–	–	2	–	–	15	5	1	2	28
Rutaceae													
Boronia caeruleum	30225	LS	–	–	–	–	–	–	–	–	–	–	–
Drummondita sp. 'A'	3144	S	–	–	–	–	–	–	–	–	–	–	–
Eriostemon brucei	3041	S	36	3	1	–	–	–	8	5	1	15	69
Eriostemon brucei var. *brevifolius*	3188	LS	3	–	–	1	–	–	2	–	–	3	9
Eriostemon deserti	3169	LS	–	–	–	1	–	–	–	–	–	3	4
Eriostemon nutans	3851	LS	–	–	–	–	–	–	–	2	–	3	5
Eriostemon sericeus	3002	S	10	–	–	–	–	–	1	–	–	3	14
Eriostemon thryptomenoides	7169	LS	–	–	–	–	–	–	–	–	1	5	6
Eriostemon tomentellus	3869	LS	–	–	–	–	–	–	–	3	–	4	7
Phebalium canaliculatum	30033	S	–	–	–	–	–	–	–	4	2	9	15
Phebalium tuberculosum	3492	S	–	–	–	–	–	–	–	1	–	1	2
Philotheca tubiflora	2675	LS	–	–	–	–	–	–	–	–	1	–	1
Santalaceae													
Exocarpos aphyllus	6805	S	6	1	9	48	12	7	23	25	–	7	138
Exocarpos sparteus	3393	S	–	–	–	–	–	–	–	1	1	–	2
Leptomeria preissiana	7263	S	–	–	–	–	–	–	–	–	–	–	–
Santalum acuminatum	2611	T	2	–	–	5	3	–	4	12	–	–	26
Santalum lanceolatum		T	–	–	–	2	–	–	–	2	–	1	5
Santalum murrayana	3078	TS	–	–	–	–	–	2	6	1	–	–	9
Santalum spicatum	2175	T	33	4	3	19	4	1	36	8	2	6	116
Sapindaceae													
Alectryon oleifolius	7432	T	–	–	–	2	1	–	2	–	–	–	5
Dodonaea amblyophylla	3397	S	–	–	–	–	–	–	–	–	–	–	–
Dodonaea inaequifolia	3261	S	17	4	7	1	–	–	3	4	–	1	37
Dodonaea lobulata	2008	S	5	1	1	1	–	–	1	–	–	–	9
Dodonaea microzyga	3060	S	9	–	–	–	–	–	1	–	–	–	10
Dodonaea petiolaris	3646	S	1	–	–	–	–	1	1	–	–	–	3
Dodonaea pinifolia	3357	LS	2	1	–	–	–	–	1	–	–	–	4
Dodonaea rigida	3057	S	11	3	–	–	–	–	3	4	–	1	22
Dodonaea viscosa		S	16	–	2	–	–	–	–	1	–	–	19
Dodonaea viscosa subsp. *angustissima*	2146	S	–	–	1	10	2	–	3	8	1	1	26
Scrophulariaceae													
Stemodia florulenta	30073	LS	–	–	–	–	–	–	1	–	–	–	1
Stemodia viscosa	3532	LS	–	–	–	–	–	–	–	–	–	–	–
Solanaceae													
Anthotroche pannosa	3455	LS	–	–	–	–	–	–	–	–	1	3	4
Duboisia hopwoodii	6732	S	–	–	–	–	–	–	–	–	–	1	1
Lycium australe	6803	S	–	–	3	11	7	4	3	–	–	1	29
Solanum ashbyae	2460	LS	2	–	–	–	–	–	–	–	–	–	2
Solanum aff. *ellipticum*	3791	LS	1	–	–	–	–	–	–	–	–	–	1
Solanum ferocissimum	2036	LS	–	–	–	–	–	–	3	–	–	–	3
Solanum horridum	2363	LS	13	4	–	–	–	–	2	–	–	–	19
Solanum lasiophyllum		S	67	55	25	55	9	7	74	19	4	12	327
Solanum orbiculatum	6847	LS	10	3	3	26	7	–	26	20	–	5	100
Solanum plicatile	2131	S	–	–	–	–	–	–	–	–	–	1	1
Solanum sturtianum	2064	S	–	–	–	–	–	–	–	–	1	–	1
Stackhousiaceae													
Stackhousia viminea	3648	LS	1	–	–	–	–	–	–	–	–	–	1

Family Botanical name	1 Collection no.	2 Growth form	A	B	C	D	E	3 Habitat group F	G	H	I	J	4 Total sites
Sterculiaceae													
Brachychiton gregorii		T	14	10	–	1	–	–	21	2	–	4	52
Keraudrenia integrifolia	3220	LS	–	–	–	–	–	–	–	–	2	5	7
Rulingia loxophylla	30140	LS	1	–	–	–	–	–	–	–	1	–	2
Rulingia luteiflora	3070	S	2	–	–	–	–	–	–	–	–	1	3
Stylidiaceae													
Stylidium dielsianum	3920	LS	1	–	–	–	–	–	–	–	–	–	1
Stylidium aff. *elongatum*	3010	LS	–	–	–	–	–	–	–	–	–	–	–
Stylidium aff. *induratum*	3219	LS	–	–	–	–	–	–	–	–	–	–	–
Stylidium longibracteatum	3263	LS	–	–	–	–	–	–	–	–	–	–	–
Surianaceae													
Stylobasium spathulatum		S	–	–	–	1	–	–	–	–	–	–	1
Thymelaeaceae													
Pimelea avonensis	3807	LS	–	–	–	–	–	–	–	–	–	–	–
Pimelea microcephala		S	11	2	–	7	4	1	8	7	2	8	50
Pimelea suaveolens	3844	LS	–	–	–	1	–	–	–	–	–	–	1
Violaceae													
Hybanthus floribundus	3061	LS	–	–	–	–	–	–	1	–	–	–	1
Xanthorrhoeaceae													
Xanthorrhoea thorntonii		TS	–	–	–	–	–	–	–	–	1	–	1
Zygophyllaceae													
Zygophyllum aurantiacum		LS	1	–	–	10	2	–	–	4	–	1	18
Zygophyllum fruticulosum	3860	LS	–	–	–	1	–	–	–	–	–	–	1

Key

1. Collecting number

Numbers in the range 3000 to 3999 and 30000 to 30270 were collected within the survey area by the rangeland survey team.

Numbers from 6799 to 7487 were collected within the survey area by R.J. Cranfield, Herbarium, Conservation and Land Management.

Numbers from 2000 to 2863 were collected in the adjoining north-eastern Goldfields survey area, and were recorded in this survey area.

2. Growth form

T	tree
M	mallee
TS	tall shrub (> 2 m)
S	shrub (1- 2m)
LS	low shrub (< 1 m)
V	vine/creeper
P	parasite
H	perennial herb
F	fern
G	grass or grass-like

3. Habitat group

The number of inventory sites in each of the following habitat groups at which the species was recorded (the total number of inventory sites in each habitat group is in brackets) ;

A	Hill, ridge and breakaway plateau sclerophyll shrubland and woodland habitats (127 sites)
B	Stony plain and low rise sclerophyll shrubland habitats (65 sites)
C	Stony plain and low rise chenopod shrubland habitats (51 sites)
D	Alluvial plain with conspicuous chenopod shrubland habitats (175 sites)
E	Calcrete or kopi associated shrubland or woodland habitats (25 sites)
F	Drainage focus sclerophyll habitats (25 sites)
G	Broad sheet flood hardpan plain sclerophyll shrubland and woodland habitats (187 sites)
H	Plains transitional to sandplain with sclerophyll shrublands and woodlands habitats (70 sites)
I	Sandplain hummock grasslands (24 sites)
J	Sandplain sclerophyll shrubland or woodland habitats (92 sites)

4. Total sites

The number of inventory sites at which the species was recorded.

Appendix 1(ii). Common perennial plants in the survey area

Trees, mallees and tall shrubs (commonly >2 m)

Acacia 'acuminata subsp. *acuminata'* MS	jam
Acacia 'acuminata subsp. *burkittii'* MS	fine-leaf jam
Acacia aneura	mulga
Acacia coolgardiensis	sugar brother, spinifex wattle
Acacia craspedocarpa	hop mulga
Acacia eremaea	snakewood
Acacia exocarpoides	
Acacia grasbyi	miniritchie
Acacia linophylla	wanyu
Acacia masliniana	spiny snakewood
Acacia quadrimarginea	granite wattle
Acacia ramulosa	bowgada
Acacia scleroperma	limestone wattle
Acacia tetragonophylla	curara
Acacia tysonii	
Acacia victoriae	prickly acacia, bardi bush
Allocasuarina acutivalvis	
Alyxia buxifolia	dysentry bush
Brachychiton gregorii	desert kurrajong
Bursaria occidentalis	native box
Callitris glaucophylla	native pine
Canthium lineare	
Casuarina pauper	black oak
Dodonaea inaequifolia	
Dodonaea microzyga	
Dodonaea viscosa subsp. *angustissima*	
Eremophila alternifolia	poverty bush
Eremophila longifolia	berrigan
Eremophila oldfieldii	
Eremophila oldfieldii subsp. *angustifolia*	pixie bush
Eremophila oppositifolia	weeooka, twin-leaf eremophila
Eremophila platycalyx	granite poverty bush
Eremophila youngii subsp. *youngii*	
Eucalyptus ewartiana	miniritchie mallee
Eucalyptus leptopoda	
Eucalyptux loxophleba	York gum
Eucalyptus salubris var. *salubris*	gimlet
Exocarpos aphyllus	naked lady, leafless ballart
Grevillea obliquistigma	
Hakea arida	
Hakea preissii	needlebush
Hakea recurva	reminder bush
Melaleuca eleuterostachya	boree
Melaleuca leiocarpa	
Melaleuca sheathiana	boree
Melaleuca uncinata	broombush
Pittosporum phylliraeoides	native willow
Santalum acuminatum	sweet quandong
Santalum spicatum	sandalwood

Shrubs (commonly 1-2 m)

Acacia andrewsii	
Acacia colletioides	wait a while wattle
Acacia erinacea	
Acacia hemiteles	tan wattle
Acacia microcalyx	
Atriplex bunburyana	silver saltbush
Atriplex nummularia	old man saltbush
Bossiaea walkeri	
Calycopeplus ephedroides	
Cratystylis subspinescens	sage
Dodonaea rigida	
Dodonaea viscosa	sticky hop bush
Eremophila decipiens	slender fuchsia
Eremophila eriocalyx	desert pride
Eremophila forrestii	Wilcox bush
Eremophila fraseri	turpentine bush
Eremophila granitica	thin-leaved poverty bush
Eremophila lachnocalyx	
Eremophila latrobei	warty-leaf eremophila
Eremophila scoparia	broom bush
Eremophila serrulata	
Grevillea paradoxa	
Grevillea pityophylla	
Lycium australe	water bush, Australian boxthorn
Maireana convexa	mulga bluebush
Pimelia microcephala	shrubby rice flower, banjine
Porana sericea	
Prostanthera althoferi subsp. *althoferi*	
Ptilotus divaricatus	climbing mulla mulla
Ptilous drummondii	
Rhagodia eremaea	tall saltbush
Rhagodia preissii	
Rhyncharrhena linearis	
Scaevola spinescens	currant bush
Senna artemisioides subsp. *artemisioides*	silver cassia
Senna artemisioides subsp. *filifolia*	desert cassia
Senna artemisioides subsp. *helmsii*	crinkled cassia
Senna artemisioides subsp. *sturtii*	variable cassia
Senna glutinosa subsp. *charlesiana*	
Senna glutinosa subsp. *chatelainiana*	green cassia
Sida calyxhymenia	tall sida
Thryptomene aspera subsp. *glabra*	
Thrytomene decussata	
Thryptomene mucronulata	

Low shrubs (commonly <1 m)

Abutilon spp	
Atriplex amnicola	river saltbush
Atriplex stipitata	bitter saltbush
Atriplex vesicaria	bladder saltbush
Borya sphaerocephala	resurrection plant
Cheilanthes austrotenuifolia	rock fern
Cheiranthera filifolia	
Chenopodium gaudichaudianum	scrambling saltbush
Cryptandra connatum	
Enchylaena tomentosa	ruby saltbush
Eremophila clarkei	turpentine bush
Eremophila compacta	felty fuchsia bush
Eremophila exilifolia	little turpentine poverty bush
Eremophila georgei	
Eremophila glabra	tar bush
Eremophila maculata	emu bush, fuchsia bush
Eremophila metallicorum	
Eremophila punicea	pink flowered poverty bush
Eriostemon brucei	
Eriostemon sericeus	
Frankenia spp.	frankenia
Grevillea deflexa	
Gunniopsis quadrifida	sweet samphire
Halosarcia spp.	samphire
Halosarcia halecnemoides	
Maireana atkinsiana	bronze bluebush
Maireana georgei	George's bluebush, golden bluebush
Maireana glomerifolia	ball-leaf bluebush
Maireana planifolia	flat-leaved bluebush
Maireana planifolia x villosa	
Maireana platycarpa	shy bluebush
Maireana pyramidata	sago bush
Maireana suedifolia	lax bluebush
Maireana thesioides	lax bluebush
Maireana tomentosa	felty bluebush
Maireana trichoptera	pink-seeded bluebush
Maireana triptera	three-winged bluebush
Maireana villosa	silky bluebush
Malleostemon tuberculatus	
Minuria cunninghamii	
Minuria leptophylla	
Mirbelia rhagodioides	
Olearia muelleri	Goldfields daisy
Olearia pimeleoides	burrobunga
Olearia stuartii	
Phebalium canaliculatum	
Ptilotus obovatus	cotton bush
Ptilotus schwartzii	horse mulla mulla
Rhagodia drummondii	Drummond's rhagodia
Sclerolaena spp.	bindii
Senna artemisioides subsp. *petiolari*	banana leaf cassia
Sida filiformis	
Sida rohlenae	
Solanum horridum	
Solanum lasiophyllum	flannel bush
Solanum orbiculatum	wild tomato, round-leaved solanum
Spartothamnella teucriiflora	mulga broombush
Zygophyllum aurantiacum	

Vines

Comesperma integerrimum	horse runner
Leichardtia australis	cogla, native pear
Thysanotus manglesianus	frilled lily creeper

Grasses

Amphipogon caricinus	grey beard grass
Amphipogon strictus	
Eragrostis eriopoda	woolly butt, wire wanderrie
Eragrostis setifolia	neverfail grass
Eriachne flaccida	claypan grass
Eriachne helmsii	buck wanderrie
Monachather paradoxa	broad-leaved wanderrie
Stipa elegantissima	feather speargrass
Thyridolepis multiculmis	soft wanderrie, mulga grass
Triodia basedowii	hard spinifex

Appendix 1(iii) Annual species collected during the survey or known to occur in the survey area

	Botanical name	Common name	Collection no.
		Forbs	
	Angianthus tomentosus	camel-grass	30024
*	*Argemone ochroleuca*	Mexican poppy	
	Atriplex semilunaris	annual saltbush	3249
	Brachycome ciliaris	variable daisy	3517
	Brachycome ciliocarpa	ciliated-fruited daisy	3016
	Brunonia australis	wild cornflower	3015
	Calandrinia aff. *primuliflora*		30034
	Calandrinia primuliflora		3297
	Calandrinia sp.		3014
*	*Carthamus lanatus*	saffron thistle	
*	*Centaurea melitensis*	Maltese cockspur	30014
	Cephalipterum drummondii	Drummonds everlasting	3022
	Chrysocephalum pterochaetum		3919
	Convolvulus aff. *erubescens*		3366
	Drosera bulbosa subsp. *bulbosa*		3530
	Drosera glanduligera		3795
	Drosera macrantha subsp. *macrantha*		3781
	Drosera macrantha subsp. *menziesii*		3763
*	*Echium plantagineum*	Paterson's curse	
*	*Emex australis*	double gee	
*	*Erodium cicutarium*	common crowsfoot	
	Erodium cygnorum	wild geranium	3020
*	*Gorteria personata*	gorteria	
	Haloragis aff. *odontocarpa*	mulga cabbage	3086
	Isotoma petraea	rock poison	30072
*	*Lamarckia aurea*		3183
	Lobelia heterophylla		3096
	Lobelia winfridae	one-flowered lobelia	3075
	Maireana carnosa	cottony bluebush	3904
*	*Mesembryanthemum nodiflorum*		3277
	Myriocephalus guerinae		3084b
	Nicotiana cavicola		30071
	Podolepis canescens		3018
	Podolepis lessonii		3017
	Ptilotus aervoides		3029
	Ptilotus exaltatus	tall mulla mulla	3158
	Ptilotus gaudichaudii		3943
	Ptilotus helipteroides		3030
	Ptilotus polystachyus	green mulla mulla	3069
	Rhodanthe chlorocephala subsp. *splendidum*	paper daisy	
	Rhodanthe propinqua		3025
*	*Rumex vesicarius*	native hops	
	Salsola kali	roly poly	
	Schoenia cassiniana		3085
	Sclerolaena cuneata		3545
	Sclerolaena densiflora		3674
	Sclerolaena fimbriolata		3507
	Senecio lautus	variable groundsel	30247
	Senecio lautus subsp. *dissectifolius*		3181
	Stackhousia muricata		3832
	Stenopetalum lineare	narrow thread petal	3831
	Streptoglossa cylindriceps		30197
	Streptoglossa odora		3520
	Swainsona beasleyana		3883
	Swainsona canescens	grey swainsona pea	3080
	Swainsona formosa	Sturt's desert pea	
	Swainsona incei		3885
	Symphyobasis macroplectra		3092
	Thelymitra sargentii		30059
	Trachymene bialata		3093
	Trichodesma zeylanica		3503

Appendix 1(iii) continued . . .

	Botanical name	Common name	Collection no.
		Forbs – continued	
	Velleia daviesii		3088
	Velleia glabrata	smooth velleia	3087
	Velleia rosea	pink velleia	
	Vittadinia sp.		3066
	Waitzia acuminata	orange immortelle	3019
		Annual grasses	
	Agrostis avenacea	blown grass	3210
	Aristida contorta	wind grass	3526
	Bromus arenarius	sand brome	3031
	Eragrostis dielsii	Murchison red grass	
	Eragrostis pergracilis		3645
	Eriachne ovata		30164
	Eriachne pulchella	pretty wanderrie	3082
	Parapholis incurva		3434
	Paspalidium basicladum		3062
	Pennisetum sp.		3511
*	*Pentaschistis airoides*	false hairgrass	3182
*	*Phalaris minor*		3361
*	*Polypogon monspeliensis*	beard grass	30025
	Sorghum species		30227
	Stipa scabra	speargrass	

* denotes naturalised species, not native to Western Australia