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An inventory of rangelands in part of the Broome Shire, Western Australia

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W.E. Cotching

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CONTENTS

Summary

The area surveyed covers about 8,664 km² of pastoral land in the Canning Basin physiographic region. It lies adjacent to the west coast of Broome Shire which is in the south-west of the Kimberley region of Western Australia. The area is described in terms of climate, geomorphology, vegetation, land systems, soils and pasture types. A land system map at a scale of 1:700,000 including Anna Plains station which was not part of the surveyed area is presented. Mapping at the land unit level is available on request.

The area is dominated by extensive sandplains and dune fields which border on the northern edge of the Great Sandy Desert. A smaller area of coastal plain occurs on the western edge of the survey area. Soils on the sandplain and dune fields are predominantly deep red sands and loamy sands. Coastal plain soils are light grey silty clays. Lateritic skeletal soils and soils with a stony surface mantle occur over a relatively small proportion of the area. Pastures are dominated by spinifex communities on the sandplain with halophytic species dominating pastures on the coastal plain.

There are no permanent water courses in the area although there are several springs on the inland margin of the coastal plain. Stock are almost entirely dependent upon man-made watering points for water.

Condition statements are presented for the whole survey area and for each land system. Assessments of pasture condition and soil condition were made for 1,128 points while traversing throughout the survey area during 1989 and 1990. Sixty-three per cent of these traverse records indicated good range condition, 21 per cent indicated fair range condition and 16 per cent indicated poor range condition. Soil erosion was not a serious problem over any part of the survey area with only 24 (2.2%) traverse observations recording minor or moderate soil erosion.

Regeneration programs are required for areas in poor range condition. This will involve measures such as reduced stocking, appropriate seasonal usage, deferment of grazing over some growing seasons, control of grazing activity by stock with fencing and feral animal control.

Estimations of carrying capacity for the pasture types of the area, at three condition levels, are presented. They were used for calculating the recommended carrying capacity in present condition and the potential carrying capacity in optimal range condition of each station as presented in separate reports produced by the Department of Agriculture.

Four of the five pastoral leases within the mapped area (Anna Plains, Frazier Downs, Shamrock and Thangoo) are currently (2005) used for grazing cattle. Each of these leases has two established monitoring systems. A Pastoralist Monitoring System (PMS) enables pastoralists to use objective assessments of indicators and trends in range condition when planning grazing management practices. The Western Australian Range Monitoring System (WARMS) enables government to be aware of changes in the condition of the land, at the district or regional level, as a result of management practices and climate.

Introduction

This survey was undertaken by the Western Australian Department of Agriculture during 1989 and 1990. The area is considered part of the Kimberley region but mapping of resource data had not been carried out during previous surveys of the region. Departmental policy is to provide rangeland inventories of all stations in the Kimberley. This survey was undertaken as part of that program and land system mapping was carried out as an adjunct. Areas to the north of the survey were land system mapped by Speck *et al.* (1964) whilst Anna Plains station to the south was land system mapped in 2004 by the Pilbara rangeland survey team. Pastures were surveyed for range condition by McKenzie (1985).

The survey covered about 8,660 km² of pastoral land in the physiographic region known as the Canning Basin (Gibson 1983). The area covered by the survey extends from the southern edge of the Roebuck Plain in the north to Mt Phire in the south and inland to about 60 km east of the coast. The area covered four pastoral leases: Thangoo, Shamrock, Frazier Downs, Nita Downs and a general lease, Shelamar, and an area of unallocated Crown land to the east of Nita Downs (Figure 1).

Although Anna Plains station was not included in this survey the map accompanying this bulletin includes Anna Plains. The map depicts an area totaling about 12,700 km².

The purpose of this survey is to provide a comprehensive description and mapping of the pastoral resources of the area, together with an evaluation of pastoral potential and the condition of the soils and vegetation. This report, with its accompanying map is primarily intended as a reference for pastoral managers, rangeland advisers and land administrators, the people most involved in planning and implementing pastoral management practices and land usage consistent with the condition, stability and potential of the natural resources. The land system maps and descriptions of landforms, soils and vegetation will also provide researchers and the public with a basic reference on the features and geography of the area.

Descriptions of the pastures and land systems of the individual stations, together with their corresponding maps at 1:100,000 scale (not provided here), provide an essential framework of resource information required for planning appropriate management for each area of a property. Such information and maps have been provided to each station as a Resource Survey Report (Cotching *et al*. 1990 a, b, c, d).

The impact of grazing management and practices needs to be monitored regularly to ensure the maintenance or improvement of the productive condition of the land. This survey provides a descriptive and comparative basis on which future trends in the condition of the rangeland can be monitored.

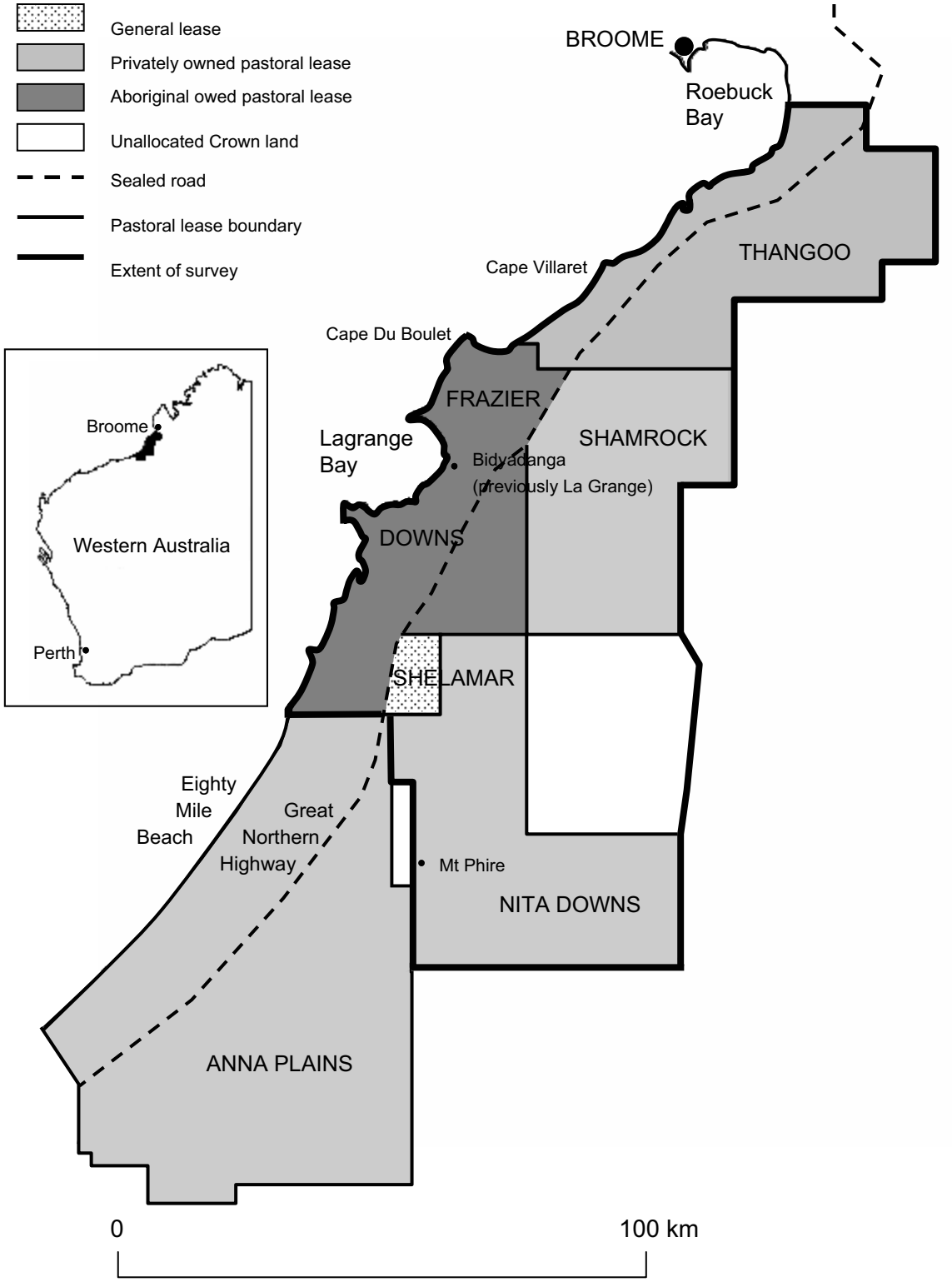


Figure 1. Location map of survey area.

Brief pastoral history

Pastoralism in the survey area began in about 1880 when Mr G.H. Roe founded Thangoo station (Battye and Fox 1915) running mainly cattle with a few sheep. In 1901 Messrs Edgar and Biddles took up the tract of country known as Yardogarra comprising 150,000 acres (60,000 ha). By 1903 when Edgar and Biddles acquired it, Engadine, a property of 100,000 acres (40,000 ha), was already held by Mr J. Eacott. In 1903 Mr W.H. James purchased La Grange Bay Downs station which was 57,000 acres (23,000 ha). This station was subsequently purchased by Edgar and Biddles. In 1910 Mr J.A. Macdonald took up a pastoral lease 80 miles (128 km) south of Broome and shortly afterwards extended his interests by purchasing the adjoining property known as Langate. These leases are presumably the area referred to now as Frazier Downs. The Nita Downs lease was first taken up in 1967 with the lease being expanded in 1982 and 1986. Shamrock station was created in 1986 from the eastern part of La Grange Bay station.

Cattle and sheep were run on the properties from the days of settlement but the country is better suited to cattle and since the early 1970s the area has only been stocked with cattle. In 2003 three of the five pastoral leases in the mapped area were stocked and carried a total of about 20,300 adult cattle.

The stations are serviced by the town of Broome which lies to the north and was declared a town site in 1883.

Climate

The area lies within a region which is described as having a semi-arid monsoonal climate. Almost all of the rainfall occurs between December and April. During the remainder of the year falls are light and sporadic, and several consecutive rainless months at this time are not uncommon.

Sources of climate data

Information presented in this section was drawn from reports by Fitzpatrick and Arnold in Speck *et al.* (1964), Bureau of Meteorology (1972) and Beard (1979). Updated rainfall information was also supplied by the Bureau of Meteorology (BOM).

Climatic factors

Rainfall

Mean and median monthly rainfall figures for stations within or close to the survey area are given in Table 1. Rainfall increases from south to north. Mean annual rainfall is lowest at Anna Plains with 356 mm and highest at Thangoo with 582 mm.

Mean rainfall figures give no indication of rainfall reliability which is of great significance in an area where rainfall is low and very seasonal. In this region rainfall in individual months often varies greatly from the mean figure and is usually below it. For example, at Broome, the average for January over a period of 62 years is 154 mm but this total has been reached in only 31 per cent of years. The figure for January which has a 50 per cent chance of being exceeded (median) is 120 mm, which is 34 mm below the mean for the month. Later in the year, in those months which are not in the tropical cyclone season, but still have a mean rainfall in the vicinity of 25 mm, this effect is more noticeable. In June the mean is 23 mm but in 75 per cent of years the month's rainfall is less than this, and the figure which has a 50 per cent chance of being exceeded is only 4 mm.

Monthly rainfall reliability decreases towards the south of the district, which means that rainfall is not only lower in the south but also less reliable. The annual median rainfall figures show that the difference in the level of rainfall received is not as extreme when the yearly interval is considered. In other words, if rainfall is abnormally low during one period of the year, it will be made up for during another period in most years.

Effective rainfall and growing season

It has been found that the growing season in the pastoral area is better represented by the sum of all the periods of growth made during the year, rather than by the length of the longest period of growth, as it is in the agricultural area. As the native pastures grow when there is sufficient water available for their use, the length of the growing season can be related to the amount of rain which falls and the rate at which it is lost by evaporation and transpiration by plants.

The length of the growing season is taken as the sum of all periods of growth during the year. None of these periods will be less than one week, but they will be of varying lengths and usually one in each year will be considerably longer than most of the others. This has been called the main growing period. The median date of the beginning of the growing season and of the main growing period are shown in Table 2 together with median values of the lengths of these periods. The table shows that the growing season starts later and is shorter in the south than in the north of the area.

Temperature

The means for the monthly maximum, minimum and extreme temperatures are given in Table 3 for three stations within or close to the survey area. Temperatures are consistently hot from November to April with an unusual feature being that the months with the highest and lowest mean maximum temperatures are only three months apart. This is due mainly to the wet conditions existing during summer causing the peak of the annual temperature curve to be delayed until April. During this month there are approximately two more hours of sunshine per day than in February. The coldest months are June, July and August. The range of temperatures is less on the coast at Broome than at the more inland Anna Plains site. Meteorological records indicate that temperatures at Nita Downs, which is further inland than Anna Plains, would be up to 2°C warmer in summer and 1-2°C cooler in winter than Anna Plains. Further inland in the Great Sandy Desert the variation is probably greater. Temperatures can be expected to exceed 37.8°C on 16 days per year on average at Broome, 32 days per year on average at Bidyadanga (La Grange) and on 55 days per year on average at Anna Plains.

Humidity

The onset of the wet season is preceded by an increase in absolute and relative humidity, reflecting large-scale advection from adjacent maritime sources. This normally commences in September and October, two of the driest months of the year. However the highest humidities are not observed until January and February; the lowest occur in July. Humidities are lower inland than on the coast.

Tropical cyclones

Tropical cyclones capable of producing strong winds, high seas and heavy rain may be experienced from late November to April, but are most common during January and February. Bureau of Meteorology records indicate that since 1910 there have been 22 cyclones that have caused gail-force winds at Broome. The frequency of cyclones that impact Broome has been less in recent times, with only two cyclones taking place between 1990 and 2004.

Cyclones that impact Broome predominantly form over the warm ocean waters to the north of the Kimberley. These systems typically travel in a west to south-westerly direction; so that the orientation of the coastline of Broome protects it from the majority of such cyclones. Cyclones that affect Broome travel in a more south to south-easterly direction. Alternatively cyclones form from lows that move offshore from the West Kimberley, whilst there may be associated heavy falls of rain; they do not often cause strong winds within the Broome area.

Cyclones have the potential to cause widespread damage due to destructive wind gusts and flooding from rain or tidal surge. Infrastructure is at risk during the cyclone season as are domestic stock if insufficient warning is given for stock to be moved to more sheltered areas.

An example of this was tropical cyclone Rosita of April 2000; Rosita was one of the most severe tropical cyclones to cross the West Kimberley in the last 100 years. It crossed the coast as a category 5 cyclone 40 kilometres south of Broome and caused severe structural damage at the Eco Beach tourist resort and at Thangoo station. A maximum wind gust of 153 km/hr was recorded at Broome Airport but wind gusts closer to the centre were estimated as greater than 250 km/hr.

Paleoclimate

The occurrence of laterites attributed to Early Tertiary age on geological evidence suggests that the climate was humid and tropical at that time. Subsequently the climate appears to have become more seasonal as well as less humid, so that by Miocene time deep weathering no longer took place. This seems to have been a steady global process during the Tertiary, accompanied also by progressive cooling. However, as the Australian continent was at the same time changing its latitudinal position by northward drift, the global cooling was largely counterbalanced by movement towards a warmer latitude (Beard 1977). By the Quaternary, general cooling had reached the point where glaciation would occur in high latitudes, and periodic ice ages lasting many thousands of years were experienced.

During the last Glacial period the climate was cooler and much drier than today whilst during the period 14,000 to 10,000 years ago there was a rapid climatic change, and since about 12,000 years ago the climate has been about as warm and wet as at present. The present climate of the Kimberley may be in a relatively humid phase.

Table 1. Mean and median monthly rainfalls (mm)

Station	Mean/Median	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	No. of years of observations
Broome	Mean	158	144	101	30	21	23	4	3	1	1	13	77	559	62
	Median	124	112	73	5	1	4	0	0	0	0	1	51	371	
Thangoo	Mean	168	148	104	30	17	17	6	1	1	2	15	73	582	56
	Median	116	113	86	2	0	1	0	0	0	0	0	41	537	
Bidyadanga (La Grange)	Mean	131	119	91	26	26	21	7	2	1	1	9	51	485	96
	Median	85	98	61	2	3	6	0	0	0	0	0	18	452	
Anna Plains	Mean	105	90	70	22	22	19	6	2	1	1	8	35	381	82
	Median	61	70	35	0	1	1	0	0	0	0	0	20	348	
Nita Downs	Mean	175	140	71	25	33	19	5	2	3	1	14	42	530	22
	Median	110	103	64	3	6	0	0	0	0	0	0	11	472	

Table 2. Growing season data

Station	Date of beginning of first period of growth	Date of beginning of main growing period	Length of season (weeks)	
			Total	Main period
Broome	27 December	13 January	17.8	13.7
Bidyadanga (La Grange)	2 January	30 January	15.1	10.9
Anna Plains	7 January	6 February	14.3	8.5

Table 3. Mean maximum, mean minimum and extreme temperatures (°C)

Station		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	No. of years of observations
Broome	Mean maximum	33.4	33.3	34.2	34.2	31.2	28.2	27.9	29.7	31.7	32.8	33.8	34.1	56
	Mean minimum	26.2	26.0	25.2	22.1	18.2	15.3	14.1	15.2	18.4	22.0	24.7	26.2	56
	Extreme high	46.4	42.7	41.7	41.7	38.3	36.2	35.0	38.1	39.7	42.8	44.0	44.8	41
	Extreme low	20.1	15.2	12.8	12.2	7.3	6.4	4.6	4.8	9.4	11.6	16.6	17.2	41
Bidyadanga (La Grange)	Mean maximum	34.3	34.1	35.4	36.2	31.8	29.8	28.9	30.4	32.1	34.2	35.1	34.8	4
	Mean minimum	25.8	25.6	25.2	22.4	18.9	15.7	13.4	14.1	16.8	20.5	23.4	25.7	4
	Extreme high	44.4	42.8	42.2	42.8	37.8	35.6	34.4	37.2	39.4	42.8	45.0	44.4	10
	Extreme low	19.4	20.6	17.2	11.7	10.6	3.9	6.1	5.6	9.4	8.9	16.3	18.9	10
Anna Plains	Mean maximum	35.1	35.2	36.3	35.4	31.9	28.3	28.2	30.6	33.4	34.3	35.8	36.3	20
	Mean minimum	25.5	25.3	24.0	20.6	16.6	13.3	11.7	12.9	15.7	19.2	22.2	24.4	20
	Extreme high	46.1	44.3	43.9	42.2	38.6	35.0	35.0	37.8	41.7	44.4	46.7	46.7	20
	Extreme low	18.3	16.7	14.6	8.7	1.9	1.2	2.8	4.1	6.4	10.0	12.8	15.6	20

Geology and geomorphology

The geology of the survey area has been mapped by the Bureau of Mineral Resources, Geology and Geophysics at a scale of 1:250,000. The area occurs on the La Grange and Munro map sheets for which explanatory notes have been written by Gibson (1983) and Towner (1982) respectively.

Regional geology

The survey area lies in an area of sedimentary deposition known as the Canning Basin. The geological history of the basin has been dominated by periods of regression and transgression of the sea. In Precambrian times, sediments were laid down, igneous rocks intruded them, and metamorphism took place. These rocks form the basement of the Canning Basin. Four periods of sea transgression occurred in Early and Late Ordovician, Early Permian and Jurassic times when the entire area was covered by sea and sedimentation occurred. Intervening periods of emergence resulted in erosion and peneplain formation. During the Cretaceous a shallow sea covered the area in which mud and fine sand were deposited followed by fluvial to deltaic sediments. These Cretaceous sediments are those comprising the hills in the area such as Parda Hill, Willara Hill and Mt Phire. Land emergence occurred in Late Cretaceous times so that during the Tertiary, weathering and erosion took place resulting in laterite formation and a few mesas.

During Quaternary times, material overlying the laterite was reworked into the current sandplain and fields of longitudinal or seif dunes. When the dunes were forming between 25,000 and 14,000 years ago the climate was arid and the winds were up to 30 per cent stronger than today (Davidson 1989). During Quaternary times the sea level was slightly higher than at present and estuarine sediments were deposited from Roebuck Plains in the north to the Eighty Mile Beach area in the south.

These plains now lie above high tides for the most part, indicating a slight fall in sea level in more recent times. Recent onshore sedimentation has resulted in the accumulation of sand in parallel ridges on beaches south of the Roebuck Plain, particularly along Eighty Mile Beach. Both the dunes of the inland dune fields and of the coastal strip are stabilised with vegetation.

Geomorphology

The surface of the Canning Basin slopes gently towards the coast and is characterised by low relief and large gently undulating aeolian sandplains. The highest point of 170 m elevation occurs 70 km east of False Cape Bossut with elevation on the coast being 30 m at the southern end of Thangoo station and on Frazier Downs where the sandplain ends as a coastal cliff. The sandplain at the southern end of the survey area on Nita Downs has an elevation of 60-100 m.

Isolated mesas and hills are present throughout the area with relief of up to 40 m above the surrounding landscape. The coastal plain has elevations generally of 5-10 m but falls to sea level on the coastal margins.

There are no permanent water courses although there are several springs on the inland margin of the coastal plain. Claypans in the south-eastern corner of the area retain water after heavy rain but these are dry for most of the year. The coastal plains are subject to flooding on rare occasions with standing water remaining for several weeks after an extreme rainfall event.

Geomorphic districts

The geomorphology of the area was first described by Jutson (1934) who recognised six physiographic divisions in Western Australia. This survey area lies on the boundary of two of these divisions: the Northern or Kimberley Division and the Sandridge Division of the Great Sandy Desert. In his 1934 work, Jutson included part of the survey area in the Fitzroy Land Division. A later work by Plumb (unpubl.) divided these Divisions into Provinces and Subprovinces.

The survey area lies within his Great Sandy Desert and Dampierland Provinces with the latter being subdivided into the La Grange Plateau and Coastal Plains subprovinces.

The geomorphic districts adopted for this report (Figure 2) are based upon the geomorphic classification of Mabbutt (1973) which classified all land forms as either erosional or depositional. Mabbutt further classified erosional surfaces on relief, and depositional surfaces on their genesis. The geomorphic districts are given in Table 4.

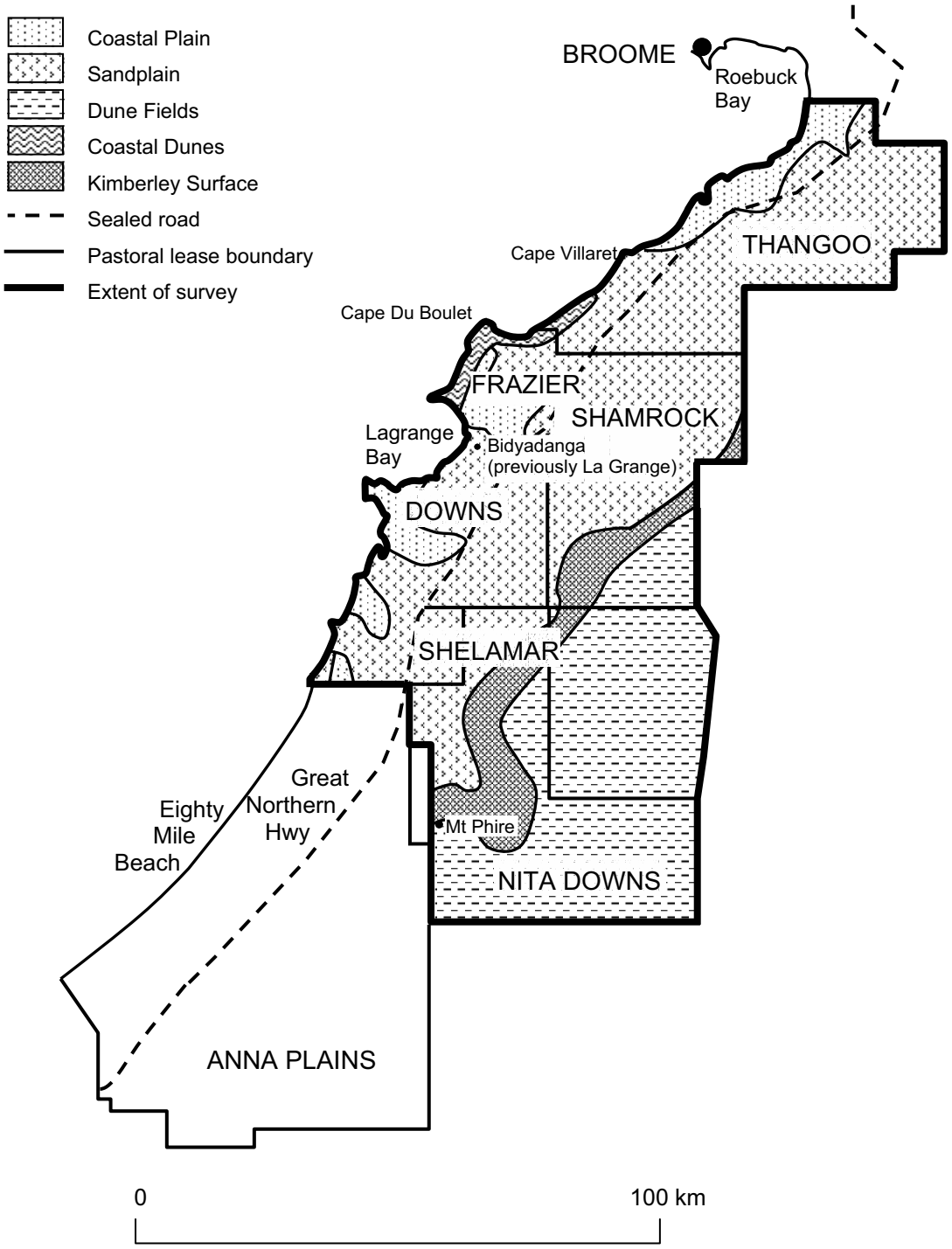


Figure 2. Geomorphic districts of the survey area (Mabbutt 1973).

Table 4. The geomorphic districts of the survey area

Surface type	Landform/Genesis	Geomorphic districts	Area within survey	
			km²	%
Erosional	Plains and hills	Kimberley Surface	735	8.5
Depositional	Aeolian	Sandplain	4,433	51.2
		Dune Fields	2,686	31.0
		Coastal Dunes	128	1.5
	Estuarine	Coastal Plains	682	7.8

Kimberley Surface District (682 km²)

The oldest landscape in the survey area is the Kimberley surface. It corresponds with the Low Kimberley surface described by Wright in Speck *et al.* (1964). It occurs as a 4-15 km wide strip running in an arc from Mt Phire in the south to the north-eastern corner of Shamrock station.

It comprises broad gently sloping plains of sedimentary sandstone and mudstone rocks of Cretaceous age. These rocks are the Parda Formation and Frazier, Melligo and Broome Sandstones. These were lateritised during Tertiary time and subsequently eroded. The products of the erosion are a few isolated mesas and hills and the extensive sandplains and dune fields. The laterite surface outcrops locally but is generally covered by 10-20 cm of sand.

Three land systems, Bulka, Parda and Phire, are found in the district. The Bulka system was originally mapped by Payne *et al*. (1979) south-east of Fitzroy Crossing. It consists of gently undulating lateritised plains with flat topped mesas. Sandplain islands and drainage depressions described by Payne *et al*. (1979) were not identified in this survey. The Bulka system is confined to the southern part of the survey area on Nita Downs. The Parda system consists of conical hills with stony ring plains which have associated alluvial plains and shallow valleys. It occurs discontinuously from just south of Parda Hill north-eastward in a line through Shamrock station. The Phire system occurs intermittently throughout the survey area with the majority being mapped in the south on Nita Downs. It was originally defined by McKenzie (1985) on Anna Plains stations which lies to the south-west of the survey area. It consists of broad stony plains with laterite gravels and low ridges of indurated sandstone outcropping. Broad drainage floors occur in run-on areas adjacent to the surrounding sandplain.

Sandplain District (4,433 km²)

This district occurs in a band of up to 60 km in width over the entire length of the survey area and is the largest district. It is characterised by extensive flat to gently undulating sandplain with little or no internal drainage and minor dune fields. The district comprises aeolian sand, derived from deeply weathered Cretaceous rocks, which were reworked during the Quaternary. Deposition ceased approximately 14,000 years ago due to increased rainfall resulting in the growth of stabilising vegetation.

Three land systems, Gourdon, Nita and Yeeda comprise this district. The Gourdon system occurs adjacent to the coast from Cape Villaret in the north to Cape Du Boulet in the south. It consists of a gently sloping sandplain and undulating laterite country with steep gullies and cliffs on the coastal margins. The system is based on Cretaceous sandstones, which outcrop at the base of the coastal gullies, with overlying aeolian Quaternary sands.

The Nita and Yeeda land systems are characterised by broad, flat to gently undulating sandplain with deep red sands. The Yeeda system was originally mapped by Speck *et al*. (1964) who identified four units of which only three were described in this survey. The Nita system was first mapped by McKenzie (1985) on Anna Plains station. It is distinguished from the Yeeda system by not having undulating topography and its more open pindan vegetation. The Yeeda system occurs to

the north of the Nita system on Thangoo, Shamrock and Frazier Downs stations whereas the Nita system occurs on Nita Downs and Frazier Downs as well as on the neighbouring Anna Plains station.

Dune Fields District (2,686 km²)

This district occurs in the south and south-east of the survey area. It comprises extensive dune fields of Quaternary aeolian sand and is included entirely within the Great Sandy land system. The longitudinal or seif dunes run in parallel ridges aligned east-west with relief averaging 8 m. The ridges are 0.5 to 1.0 km apart and were formed when the climate was more arid and windy than at present. Easterly winds were prevalent during dune formation. The dunes are now stabilised with vegetation and the only surface drainage is a series of pans in the south-east. These pans have a saline silty clay surface, hold water intermittently over the wet season, and have halophytic vegetation growing around their margins.

Coastal Dunes District (173 km²)

This district occurs as a narrow strip up to 2 km wide along the western coastal margin of the survey area. It is characterised by beach foredunes and longitudinal coastal dunes of the Eighty Mile land system. The calcareous and quartzose sands have been derived from the continental shelf by net onshore drift during the Quaternary. Most of the dunes are now stabilised by vegetation but the frontal dune is still subject to erosion and accretion during and between storm events. The dunes have relief of up to 15 m.

Coastal Plain District (693 km²)

This district occurs on the western coastal margin as a series of separate areas bordering inlets and bays over the entire length of the survey area. The northernmost area is part of the Roebuck Plain which extends up to 40 km inland. Shallow estuarine deposition of mud and minor amounts of fine sand during the Quaternary form the basis for three land systems: Anna, Roebuck and Mannerie.

The Anna system occurs in the south and appears to have been beyond tidal influence for longer than the Roebuck system. This is postulated to be due to the presence of black topsoils on areas of the Anna system where light grey estuarine mud extends to the surface on the Roebuck system. Formation of coastal dunes on the seaward margin of the Anna system was probably the mechanism for tidal exclusion over these areas. The Roebuck system occurs in tidally affected areas and as part of the Roebuck Plain. Small isolated sand dunes of low relief in the Roebuck system are of aeolian origin. Most of the Roebuck system lies above tidal influence but the lower coastal margins supporting mangroves are regularly inundated whilst high spring tides extend inland on occasions.

The Mannerie system is confined to southern areas on Frazier Downs as well as being mapped by McKenzie (1985) on Anna Plains station. The system occurs on the margin between the inland sandplain and the coastal plain. It is characterised by seepage areas and springs and is based on quartzose sands as well as estuarine mud.

Vegetation

Main vegetation features

The vegetation in the survey area is dominated by drought-resistant perennial grasses which in many areas are associated with a tall shrub community and low woodlands. A small number of botanical families contain most of the dominant perennials in the area. These are shown in Table 5. *Triodia* is pre-eminent in the pastures, *Acacia* and *Grevillea* in the taller shrub communities, and *Eucalyptus* and *Bauhinia* in the low woodlands.

The survey area lies in the Northern Botanical Province of Western Australia which has been described and mapped at 1:1,000,000 by Beard (1979). Many of the species found in the area were included in a description of the plants of the Kimberley region by Petheram and Kok (2003). Beard proposed a number of natural regions or botanical districts, with this survey area falling into the Dampier Botanical District and bordering on the Great Sandy Desert which forms the Canning Botanical District of the Eremaean Botanical Province. Beard also divided the Kimberley into three broad climatic zones with this survey area falling in the intermediate-rainfall zone which receives between 400 and 700 mm mean annual rainfall and has between 10 and 16 weeks of useful pasture growth.

When vegetation types are classified according to the dominant stratum it becomes apparent that vegetation is related to the geomorphic districts previously described in the section on geomorphology. The association of vegetation with geomorphic districts results from the controlling influence of lithology over soil type and consequently the native flora. The vegetation classes associated with each geomorphic district are shown in Table 6.

The table has been kept relatively simple but in reality there are minor amounts of several classes within most geomorphic districts, e.g. in the Coastal Plain district the diversity of classes was such that three classes were included.

Table 5. Major families and dominant perennial genera in the survey area

Family	General
Poaceae	*Aristida, Cenchrus, Chrysopogon, Eriachne, Sorghum, Sporobolus, Triodia*
Mimosoideae	*Acacia*
Caesalpinioideae	*Bauhinia*
Proteaceae	*Grevillea, Hakea*
Apocynaceae	*Carissa*
Chenopodiaceae	*Halosarcia*
Meliaceae	*Owenia*
Rubiaceae	*Gardenia*
Myrtaceae	*Corymbia, Eucalyptus*

Table 6. Vegetation classes associated with geomorphic districts

Geomorphic District	Vegetation
Kimberley Surface	Steppe grassland
Sandplain	Pindan shrubland
	Sparse low-tree steppe
Dune Fields	Sparse tree steppe
Coastal Dunes	Short bunch-grass savannah
Coastal Plain	Thicket shrubland
	Short bunch-grass savannah
	Mangrove shrubland

Fire and humans influence

Fire is both a natural and a human-induced phenomenon. Lightning strike fires are relatively common and can burn out large tracts of pindan vegetation. However, lightning fires observed on the edge of the Great Sandy Desert tend to be more restricted in their extent and usually burn out within a few hours. Pastoralists and Aboriginal people both use fire. Pastoralists use it mainly as a means of inhibiting the spread of wild fires and to promote growth of palatable pastures and other uses include shrub control. The combined effect of fire and grazing on the predominantly spinifex-based pastures are not well researched in the Kimberley but believed to lead to pasture degradation in some situations. Aboriginal people often use fire as a means of harvesting native fauna which are part of their primary food source. Sometimes areas are repeatedly burnt at short intervals and this results in poor pasture composition for cattle grazing.

Beard (1979) gave the following account of the effect of fire on pindan vegetation.

> "Essentially the pindan is a grassland wooded by a sparse upper layer of trees and a dense, thicket-forming middle layer of unarmed, phyllodal *Acacia*. It has, however, many aspects, being subject to fire which destroys the ground layer and the middle *Acacia* layer, leaving the trees intact. The grasses regenerate from seed or rhizomes, the *Acacia* from seed. The grasses are quickly re-established and for the first season or two after fire the pindan has the aspect, according to local rainfall, of a tree steppe, tree savannah or savannah woodland. Gradually the *Acacia* shrubs regenerate, grow taller and become dominant, suppressing the grasses, forbs and small woody plants. After a certain number of years the aspect is three-layered, with scattered trees, a shrub thicket and a sparse ground layer. Later still the *Acacia* individuals reach the height of the trees, which disappear from view, giving the aspect of a taller thicket or low forest of *Acacia.*"

Europeans have introduced grazing sheep and cattle to the native flora of the survey area, but changes as a result of grazing have not previously been documented. This report highlights the grazing induced changes that have occurred to the land systems. It indicates that some systems and pasture types are much more susceptible than others.

Introduced pasture plants including *Cenchrus* spp. (buffel and Birdwood grass) and *Stylosanthes* spp. (Townsville stylo and hamata stylo) are present in the survey area with *Cenchrus* pastures adapting well to particular environmental niches and providing valuable stock feed. *Stylosanthes* spp. are very restricted in their occurrence and appear not to colonise readily.

Detailed accounts of vegetation types

Details of the structure and composition of particular plant communities are given in the chapters on pasture types and land systems.

Survey methods

Methods

This survey followed the land system approach to resource description and evaluation as was used in mapping the West Kimberley by the CSIRO (Speck *et al.* 1964, Payne *et al*. 1979).

A land system is defined by Christian and Stewart (1953) as 'an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation'.

Each land system has a characteristic pattern able to be seen on aerial photographs. Generally land systems occur over an area greater than 5 km² and are therefore of a scale suitable for mapping at 1:250,000. Land systems consist of smaller land units or elements, each of which has a distinct photographic pattern. The relative proportion of the component units and their arrangement one to another gives the broader photographic pattern that characterises the particular land system.

Prior to field work commencing, tentative land systems and their likely boundaries were identified and marked onto the most recently available 1:50,000 scale black and white aerial photographs. Stereoscopic pairs of photographs were used and boundaries plotted with the aid of a mirror stereoscope. Published background information on geology, landforms, soils, vegetation and land systems was gathered from various sources to aid this initial interpretation. This included the Geological Survey of Western Australia (1:250,000 map sheet series), vegetation information from Beard (1979) and land system information from, McKenzie (1985), Payne *et al.* (1979) and Speck *et al.* (1964). False colour images generated from Landsat satellite data were also used to provide overviews of the area.

Field work

Field work was carried out from December 1989 to March 1990. The work was divided into distinct phases on each station. The first was making a plan of the station and its infrastructure together with a reconnaissance of land systems and vegetation types. All station tracks were travelled and most fence lines.

Distances and bearings were recorded on 1:100,000 topographic map sheets to enable an accurate plan to be produced. All fences, tracks, bores, mills, yards and buildings were plotted.

The second phase involved traversing most of the station tracks to give a reasonable coverage of the land systems. At 1 km intervals assessments of erosion status and pasture condition were made and recorded together with the land system, land unit, pasture type and plant species present. Stops were also made at 118 inventory sites where the landforms, surface geology, drainage features, soil erosion, soil profile and vegetation were all described. Many other diversions were made from the traverse routes to check land system and unit boundaries.

The traverses satisfied survey requirements by:

1. Providing sufficient ground control to map each area into land systems and land units on aerial photographs.
2. Visiting inventory sites or query points, chosen according to their photo-pattern, and describing the landform, soils and vegetation of the land unit concerned.
3. Characterising the land systems encountered.
4. Attempting to identify grazing-related changes in vegetation or soils and characterising range condition states within particular land units.
5. Assessing the condition of perennial vegetation and soil erosion status at 1 km intervals throughout the traverse according to criteria applicable to each land unit and vegetation type encountered.
6. Estimating stock carrying capacities appropriate for the conservation of resources within each pasture type and land system.

Site inventory techniques

Site selection

Inventory sites were selected according to:

1. Aerial photo-pattern and land unit identification.
2. The cumulative coverage of such sites achieved at the time.
3. The relative abundance of the type of photo-pattern or land unit within the broader land system.
4. The degree to which the site was likely to have been subjected to grazing pressures so that a range of grazing-related changes could be identified.

Site identification, marking and photographic record

The location of each inventory site was marked on the aerial photograph and transferred to the appropriate 1:100,000 topographical sheet and the Australian Map Grid (AMG) co-ordinates were recorded to the nearest 100 m. Oblique photographs, in colour transparency and for colour print, were taken from the top of a vehicle with an identification plate in the foreground. Site locations are shown in Figure 3.

Landscape features

General information on land systems and land unit relationships was recorded on an *ad hoc* basis as notes and sketches in a field work notebook.

Specific data on the following site attributes were routinely recorded:

Date
Station
Traverse number and location on traverse
Aerial photograph: year, run, number
AMG reference and map sheet
Land system
Land unit
Surface geology (soil parent material)
Land form
Slope and position
Erosion type and severity
Surface condition

Soil

Soil profiles were described from pits dug to 70-100 cm depth. Profile characteristics and horizon textures were used to classify each soil according to Northcote (1979). Data collected at each site included:

Moisture conditions

Soil horizon details for each horizon:

- depth
- colour
- texture
- consistence
- structure
- roots
- inclusions
- boundary

Principal Profile Form

Great Soil Group

Vegetation

Some attempt was made to identify every plant found on each inventory site. Specimen material was collected and sent to the Western Australian Herbarium for identification. Vegetation was recorded in three categories – upper storey (trees), middle storey (shrubs), and ground storey (pasture grasses). Pasture species were recorded as being desirable, intermediate or undesirable. A broad pasture type, e.g. Soft Spinifex (SOSP) was assigned to the site.

Range condition, in terms of disparity from the optimal soil surface and perennial cover-composition for the site, was assessed in the field on a nominal scale from very good to very poor as defined in the following section.

Condition assessment by traverse

A traverse method very similar to that described by Payne, Mitchell and Holman (1988) was used to achieve comprehensive coverage and a large number of assessments on each station by a distance-sampling procedure.

The method involved continuous accurate positioning of the traverse vehicle while travelling along a mapped course, usually a station track or minor road. At intervals of

1 km from the starting point, the particular land system and land unit being crossed at the time was identified and noted. The soil erosion status and pasture condition were then assessed over an area up to 100 m either side of the kilometre point. At each point the vehicle was stopped and data recorded. Two assessors were present to resolve difficulties in assigning ratings to difficult or unusual sites.

During the survey, assessments were made at a total of 1,128 traverse points on 11 land systems. The traverse routes are shown in Figure 4.

The definitions and numerical ratings for soil erosion and pasture condition are shown in Tables 7 and 8 respectively.

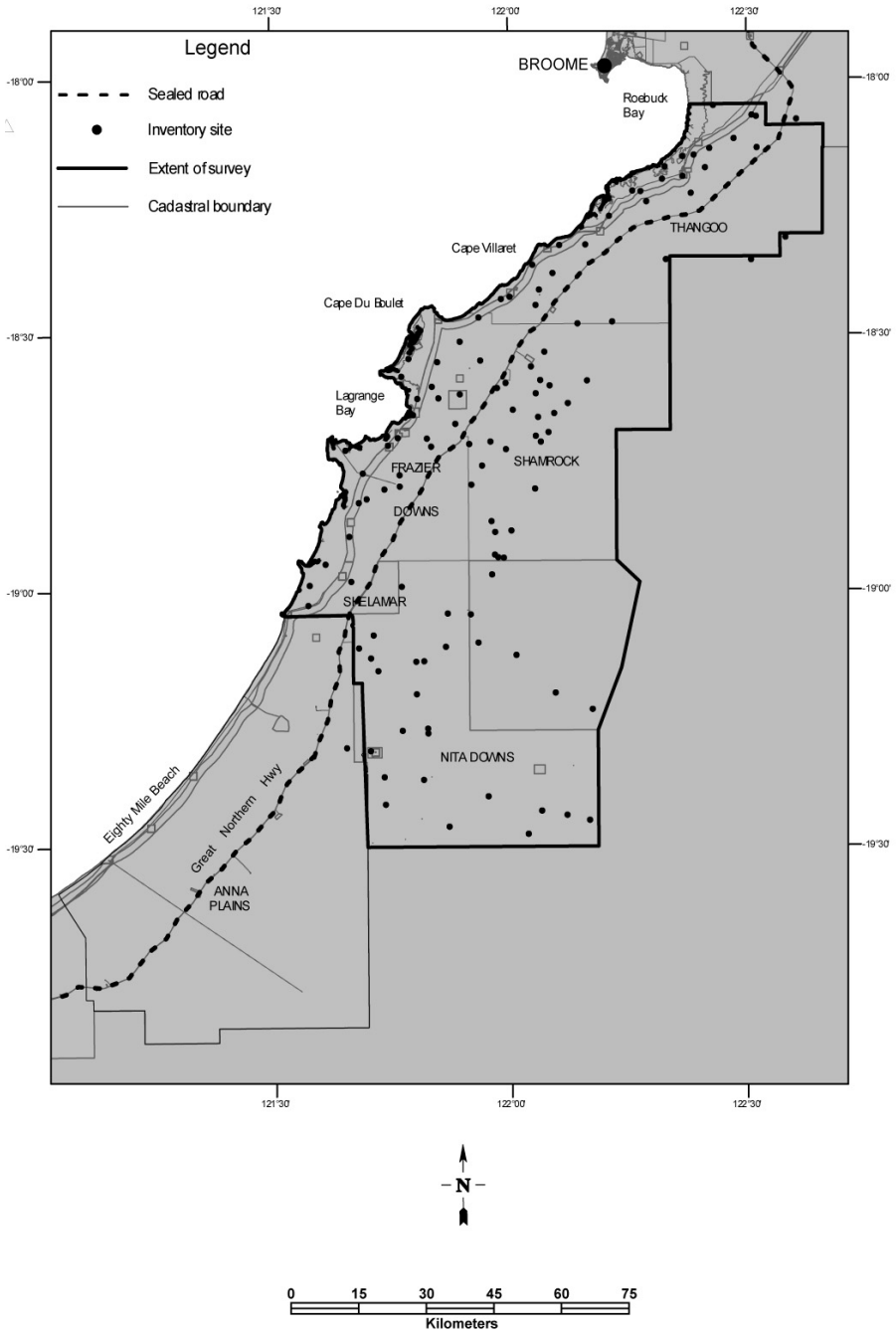


Figure 3. The distribution of inventory sites in the survey area.

Table 7. Criteria for erosion ratings

Wind erosion		
Severity	**Rating**	**Comment**
Nil	0	**No erosion**
Minor	1	**Litter redistribution and small scalds** Small isolated scalds on which the surface shows some degree of polishing. Redistribution of soil to the margins of the scald, or minor build-up of soil material around obstacles.
Moderate	2	**Large isolated scalds and hummocks** Stripping of the soil surface and build-up against obstacles associated with large but generally discontinuous scalds; or, numerous small scalds scattered throughout the site.
Severe	3	**Major deflation of soil surface** Active stripping resulting in large continuous scalds with polished and sealed surfaces. Frequent large hummocks against obstacles. In sandy systems, major dune drift. Plant cover very sparse to absent.
Water erosion		
Severity	**Rating**	**Comment**
Nil	0	**No erosion**
Minor	1	**Riling or thin sheeting** Patchy rilling and small gullies affecting small areas or thin sheeting (1-2 cm) and breaking of the surface seal on parts of the site. Some redistribution of soil and litter downslope. Much undisturbed ground between affected areas.
Moderate	2	**Gullies and/or sheeting** Gullies on the lower slopes or more susceptible parts of the site, these being capable of extension to less susceptible areas. The gullies may be associated with extensive but discontinuous disturbance of the soil surface by sheet erosion and redistribution of soil material.
Severe	3	**Terracing or extensive gullies** Sheeting or terracing affecting nearly all of the site. Redistribution of soil and exposure of subsoil or rock material. The sheeting may be associated with or replaced by very extensive gullying over most of the site.

Table 8. Criteria for pasture condition ratings

Pasture condition	
Rating	**Condition indicators**
1	**Very good** For the land unit-vegetation type, 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 liable to reduce production potential.
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.

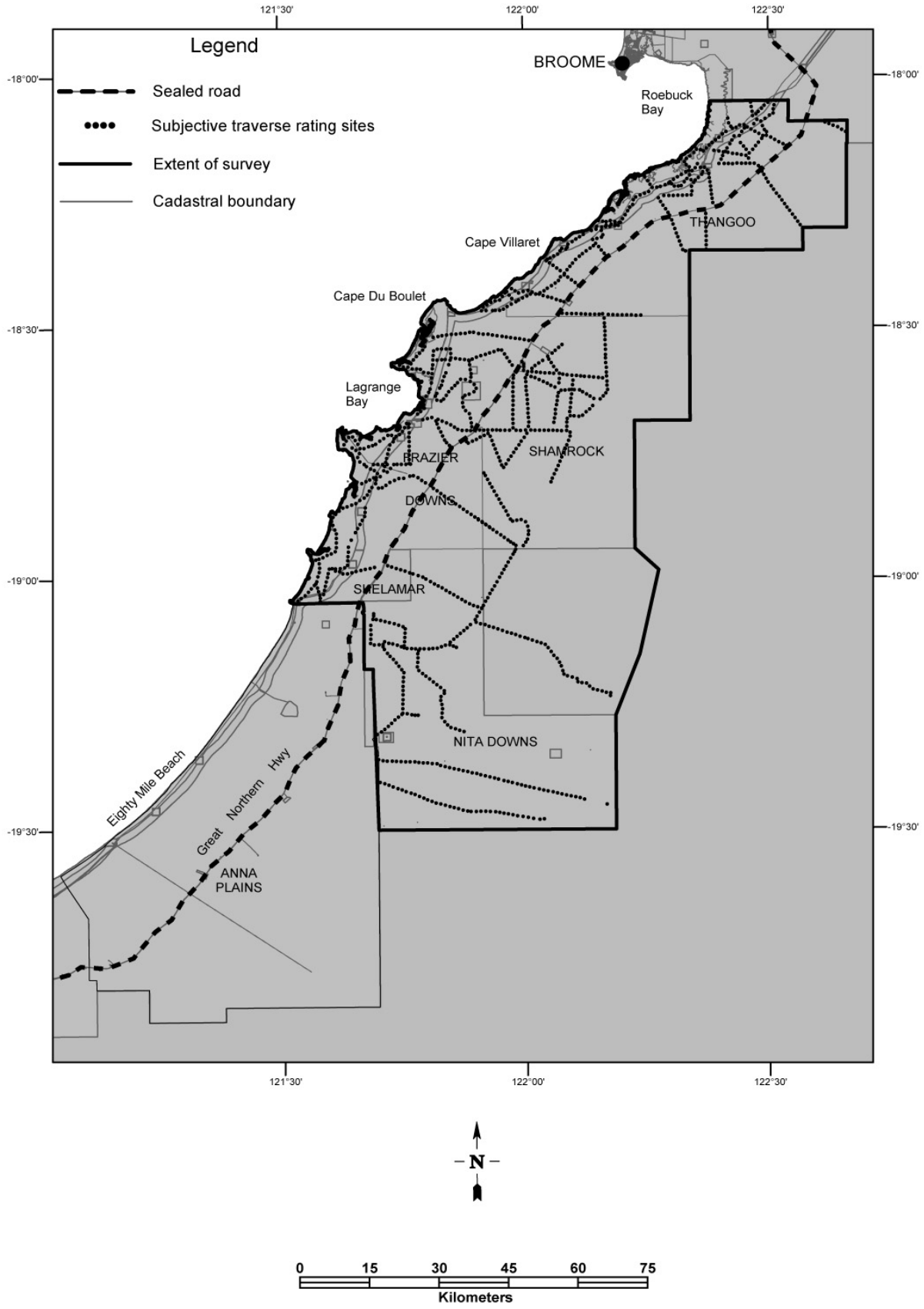


Figure 4. Traverse routes in the survey area.

Analysis of the field data

The traverse data were collated and tabulated on a land unit, land system and pasture type basis. This information, together with inventory point data and notes was used to draw up the land system and pasture type descriptions presented in this report and the individual station reports published separately. A table summarising the traverse ratings of erosion and pasture condition is presented in each station report followed by a table of recommended current and potential carrying capacity expressed in cattle units (one cattle unit is defined as a dry cow or a steer in excess of two years of age) based on overall range condition. This information has been collated and presented for the whole survey area in this report.

Range condition

Assessments of overall range condition were made by taking into account the condition of the two basic range resources - soil and pasture. Three levels of range condition were selected. These levels were termed good, fair and poor and were derived by combining total erosion and pasture condition data obtained on traverse into rational groupings as shown in Table 10. Total erosion was derived by combining the wind and water erosion traverse recordings into rational groupings as shown in Table 9.

The collated traverse data were used for preparing general condition statements for each land system as presented in the chapter on range condition.

Table 9. Derivation of total erosion

Wind erosion	+	Water erosion	=	Total erosion
Nil		Nil		Nil
Nil		Minor		Minor
Minor		Nil		Minor
Minor		Minor		Minor
Nil		Moderate		Moderate
Minor		Moderate		Moderate
Moderate		Nil		Moderate
Moderate		Minor		Moderate
Moderate		Moderate		Moderate
Nil		Severe		Severe
Minor		Severe		Severe
Moderate		Severe		Severe
Severe		Nil		Severe
Severe		Minor		Severe
Severe		Moderate		Severe
Severe		Severe		Severe

Table 10. Derivation of range condition

Total erosion	+	Pasture condition	=	Range condition
Nil		Very good		Good
Nil		Good		Good
Minor		Very good		Good
Minor		Good		Good
Nil		Fair		Fair
Minor		Fair		Fair
Moderate		Very good		Fair
Moderate		Good		Fair
Nil		Very poor		Poor
Nil		Poor		Poor
Minor		Very poor		Poor
Minor		Poor		Poor
Moderate		Fair		Poor
Moderate		Poor		Poor
Moderate		Very poor		Poor
Severe		Very good		Poor
Severe		Good		Poor
Severe		Fair		Poor
Severe		Poor		Poor
Severe		Very poor		Poor

Map preparation

Stereoscopic pairs of monochrome aerial photographs at 1:50,000 scale were used during the survey to delineate land system boundaries and to record the position of range inventory sites. Traverse point positions and assessment scores were then plotted onto 1:100,000 scale topographical maps together with inventory site locations.

Maps were produced using a computer-based Geographic Information System (GIS). Information from 1:100,000 topographic maps was initially inputted plus cadastral boundaries. Station infrastructure obtained during the first phase of field work and recorded on topographic maps was then included. A tracing was made of the land system and land unit boundaries recorded on the 1:50,000 air photographs by matching together photos in a mosaic. This tracing was then copied onto the GIS database. Traverse points and assessment scores plus inventory and monitoring site locations were added. Each data set described above was inputted on a separate level. General and land system legends were also included.

Coloured maps showing station infrastructure and land system boundaries (and in some cases land unit boundaries) were produced at 1:100,000 scale and supplied to each station together with their individual station resource inventory survey report (Cotching *et al.* 1990a,b,c,d).

The four station maps covering the original survey area were combined with a map of Anna Plains station to produce the land system map which accompanies this report.

Land systems

Fourteen land systems are shown on the map accompanying the report. Eleven of these systems are described, in alphabetical order, in the following section. Six of the 11 systems were originally described further south on Anna Plains station (McKenzie 1985), two were described in the West Kimberley area (Speck *et al.* 1964) and one was first described in the southern Kimberley area (Payne *et al.* 1979). In most instances there are minor differences between the original descriptions and those presented here, due mainly to natural gradations in landforms and vegetation.

The additional three systems shown on the map but not described in the report are: Carpentaria (described by Speck *et al.* 1964) on Thangoo station, Little Sandy on Anna Plains station (described by Van Vreeswyk *et al.* 2004) and Mandora, an undescribed system, on Anna Plains.

In each instance, the land system is described by a format which includes the following key features:

1. A statement of total area and its proportion of the survey area.
2. A summary of the key descriptive features of the system.
3. A statement indicating on which station(s) the system occurs.
4. A summary of the systems value for pastoral use, its estimated carrying capacity and range condition in 1989-1990.
5. A block diagram or plan view of a representative or stylised portion of the system, depicting component land units.
6. Tabulated summary descriptions of each land unit.

Information on land units is presented under the following headings.

Landforms

Indication of the type of unit (hill, dune, plain), its relief relative to other units, linear extent and slopes and its map symbol is given.

Soils

The Great Soil Group (Stace *et al*. 1968) is given followed by colours, textures and inclusions and the principal profile forms (Northcote 1979).

Vegetation

The vegetation class (Beard 1979) predominating is given followed by the dominant and characteristic species of grasses, shrubs and trees. The pasture types found in the unit are also listed and further information on these can be found in the chapter on pasture types.

Comments

The intensity of coverage achieved during the survey is given plus notes on erosion, where relevant.

ANNA LAND SYSTEM* (113 km², 1.3% of survey area)

(after McKenzie, 1985)

Paleo-tidal coastal plain with saline soils supporting tussock grasses and halophytic vegetation.

Geology: Quaternary estuarine and littoral calcareous mud.

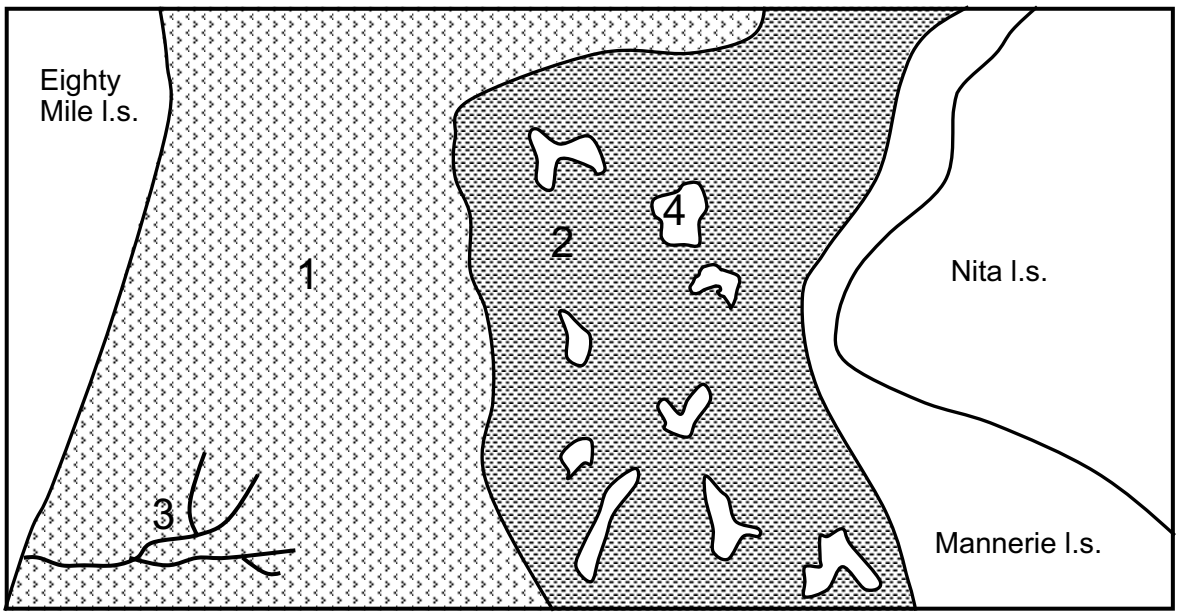
Geomorphology: Depositional surface of saline coastal flats elevated above tidal influence or cut off by coastal dunes; broad flat plains.

Location: Frazier Downs, Anna Plains.

Pastoral use: A highly productive system with Samphire/Salt Water Couch pastures (SASW) and minor amounts of Samphire (SAMP) and Cenchrus (CENC) pastures. This system is not prone to erosion and is stable under relatively high grazing pressure.

Estimated carrying capacity, good condition: 9 ha/cattle unit.

Range condition summary: Good 64%, fair 24%, poor 12% (1989-90)



Units and proportion of land system area

1.	Tussock grass plains	50%
2.	Saline plains	40%
3.	Drainage lines	5%
4.	Saline depressions	5%

* The Anna land system has been redescribed by Van Vreeswyk *et al*. 2004.

Anna land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Tussock grass plains:** paleo-tidal plains, up to 4 km wide, 6-10 m above sea level. (Ann 1)	Solonchak; black silty clay loam topsoil over light grey silty clay subsoil; Uf 6.51.	Short bunch-grass savannah dominated by *Sporobolus virginicus, Cenchrus ciliaris, Halosarcia indica* ssp. *julacea* and *Dichanthium fecundum* also present. Pasture types: Samphire/Salt Water Couch, Cenchrus.	Traversed; 1 site inventory.
2.	**Saline plains:** paleo tidal plains up to 8 km in extent, 6-10 m above sea level. (Ann 2)	Solonchak; black silty clay loam topsoil over light grey silty clay subsoil; Uf 6.51.	Short bunch-grass savannah dominated by *Sporobolus virginicus* and *Cynodon dactylon. Halosarcia indica* and *Cenchrus ciliaris* also present. *Acacia ampliceps* and *Melaleuca acacioides* on inland margins. Pasture types: Samphire/Salt Water Couch, Samphire, Cenchrus.	Traversed; 4 site inventories.
3.*	**Drainage lines:** poorly defined internal drainage lines.	Very dark medium clays.	Mainly *Cynodon dactylon.*	Not sampled.
4.*	**Saline depressions:** often bare depressions.	Super-saline clays.	Mainly *Halosarcia* spp.	Not sampled.

* These units described by McKenzie (1985) not seen or mapped during this survey.

BULKA LAND SYSTEM (28 km², 0.3% of survey area)

(after Payne *et al.* 1979)

Gently undulating plains with occasional low scattered hills supporting lobed spinifex grassland.

Geology: Mudstone of Mesozoic age, laterite and minor Quaternary aeolian sand deposits.

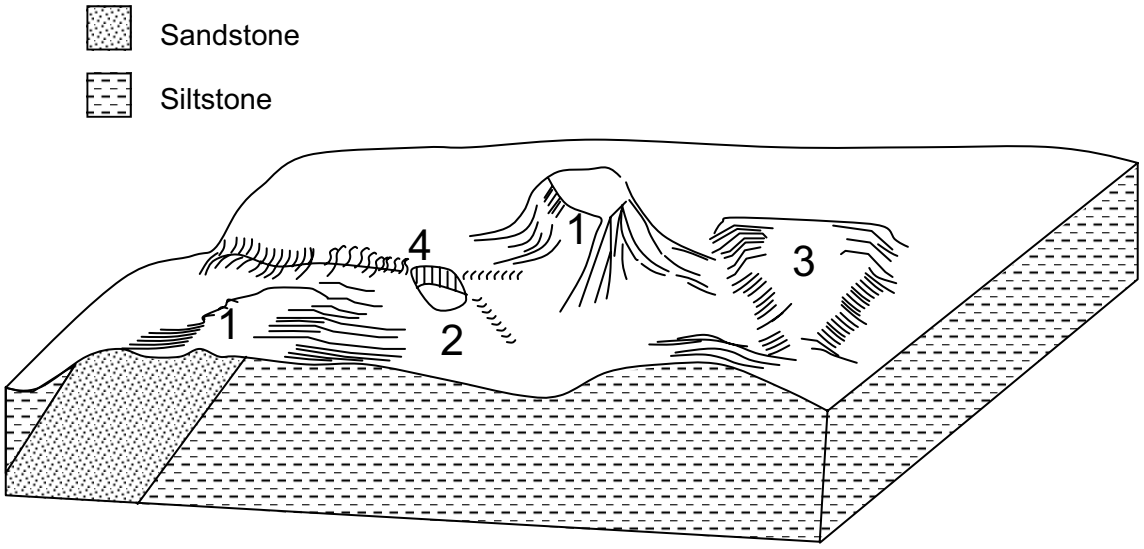
Geomorphology: Erosional surface formed by erosion of the Kimberley surface; flat topped mesas with laterite ring plains.

Location: Nita Downs.

Pastoral use: Very low productivity Lobed Spinifex (LOSP) pastures not prone to erosion.

Estimated carrying capacity, good condition: 100 ha/cattle unit.

Range condition summary: Good 100%, fair 0%, poor 0% (1989-90).



Units and proportion of land system area

1.	Hills and low rises	10%
2.	Undulating plains	60%
3.	Sandplain islands	25%
4.	Pans and drainage depressions	5%

Bulka land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Hills and low rises:** up to 40 m high, flat topped mesas up to 1.5 km long with steep side slopes up to 40%. (Buk 1)	Lithosols; outcrops of mudstone and sandstone.	Steppe grassland dominated by *Triodia intermedia* with very scattered *Acacia* spp. shrubs. Pasture type: Lobed Spinifex.	Inaccessible to stock. Site visited.
2.	**Undulating plains:** Gently inclined plains with occasional laterite outcrop, lateritised shale strew. (Buk 2)	Lithosols; shallow reddish brown coarse sandy loams over laterite and mudstone; KS Uc 5.22.	Steppe grassland dominated by *Triodia intermedia* with very scattered *Acacia translucens* and *Eremophila bignoniiflora.* Pasture type: Lobed Spinifex.	1 site inventory. A few low termite mounds present.
3.*	**Sandplain islands:** up to 1.6 km wide.	Deep red sands with patches of thin laterite strew.	Open grassy shrubland of *Triodia bitextura, Acacia tumida* and *Grevillea wickhamii.*	Not sampled.
4.*	**Pans and drainage depressions.**	Grey tough alluvial clays and depressions of sandy loam soils.	Low fringing woodlands and grasslands of *Triodia bitextura, Triodia pungens* and *Eucalyptus pruinosa.*	Not sampled.

* These units described by Payne *et al*. 1979 not seen or mapped during this survey.

EIGHTY MILE LAND SYSTEM* (70 km², 0.8% of survey area)

(after McKenzie, 1985)

Beach foredunes and longitudinal coastal dunes supporting short bunch-grass savannah.

Geology: Aeolian calcareous coastal sand.

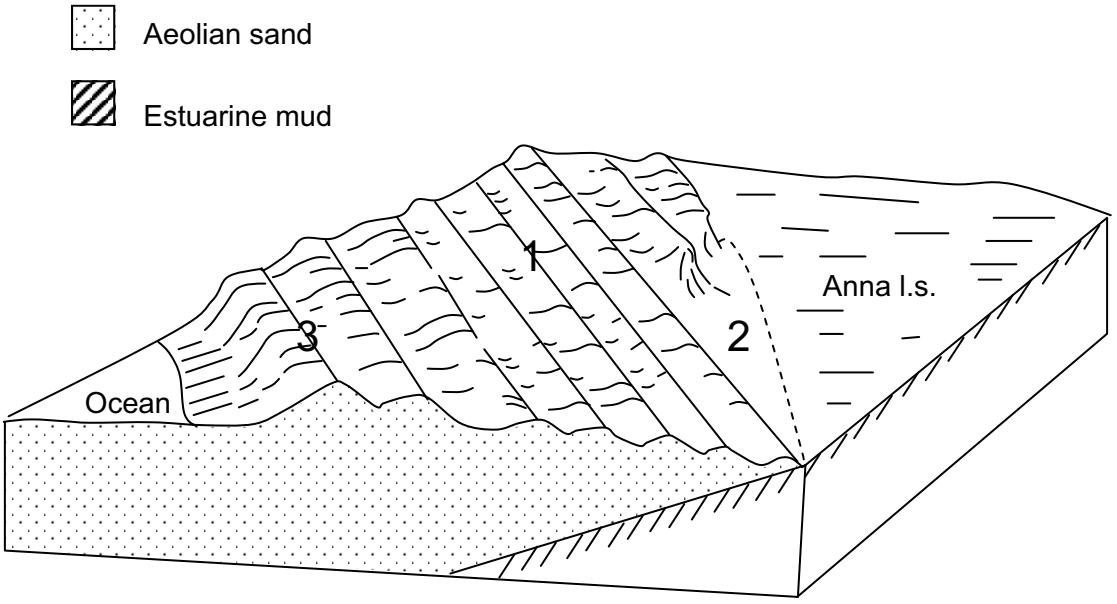
Geomorphology: Longitudinal coastal dunes stabilised by vegetation with foredunes susceptible to wave cut erosion and blowouts, no drainage features.

Location: Frazier Downs, Thangoo, Anna Plains.

Pastoral use: A low productivity system with Coastal Dune (CSDN) pastures with minor areas of high pastoral potential Cenchrus (CENC) pastures. Use is limited by a lack of stock watering points and risk of initiating wind erosion.

Estimated carrying capacity, good condition: 60 ha/cattle unit. (Areas of predominantly buffel grass 20 ha/cu.)

Range condition summary: Good 75%, fair 0%, poor 25% (1989-90).



Units and proportion of land system area

1.	Consolidated dunes	55%
2.	Marginal plains	40%
3.	Beach foredunes	5%

* The Eighty Mile land system has been redescribed by Van Vreeswyk *et al*. 2004.

Eighty Mile land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Consolidated dunes:** closely spaced low relief dunes; unit up to 2 km wide. (Eig 1)	Siliceous sands and calcareous sands; loose pale brown sands; Uc 1.21.	Short bunch-grass savannah dominated by *Whiteochloa airoides* and *Triodia pungens,* minor *Cenchrus ciliaris, Spinifex longifolius* and *Aerva javanica.* Pasture type: Coastal Dune.	Traversed; 2 site inventories. Stabilised by vegetation but susceptible to wind erosion if disturbed.
2.*	**Marginal plains:** sandplain sloping to adjacent Anna land system.	Dusky red calcareous sand.	Short bunch-grass savannah dominated by *Cenchrus ciliaris* and *Whiteochloa airoides,* some *Dichanthium fecundum* and *Panicum cymbiforme.*	Not sampled.
3.	**Beach foredunes:** unconsolidated, largely stabilised foredunes; up to 500 m wide and 15 m high with slopes up to 55%. (Eig 3)	Siliceous sands; loose pale brown sands with shell fragments; Uc 1.21.	Tussock grassland dominated by *Spinifex longifolius* with minor *Salsola tragus* and *Crotalaria cunninghamii*. Pasture type: Coastal Dune.	Traversed; 1 site inventory. Susceptible to wave cut erosion during storms and blowouts.

* This unit described by McKenzie (1985) not sampled or mapped during this survey.

GOURDON LAND SYSTEM (65 km², 0.8% of survey area)

Sandplain and undulating lateritic country with steep coastal gullies supporting spinifex grasslands with scattered trees.

Geology: Quaternary aeolian sands overlying Cretaceous sandstone and some mudstone.

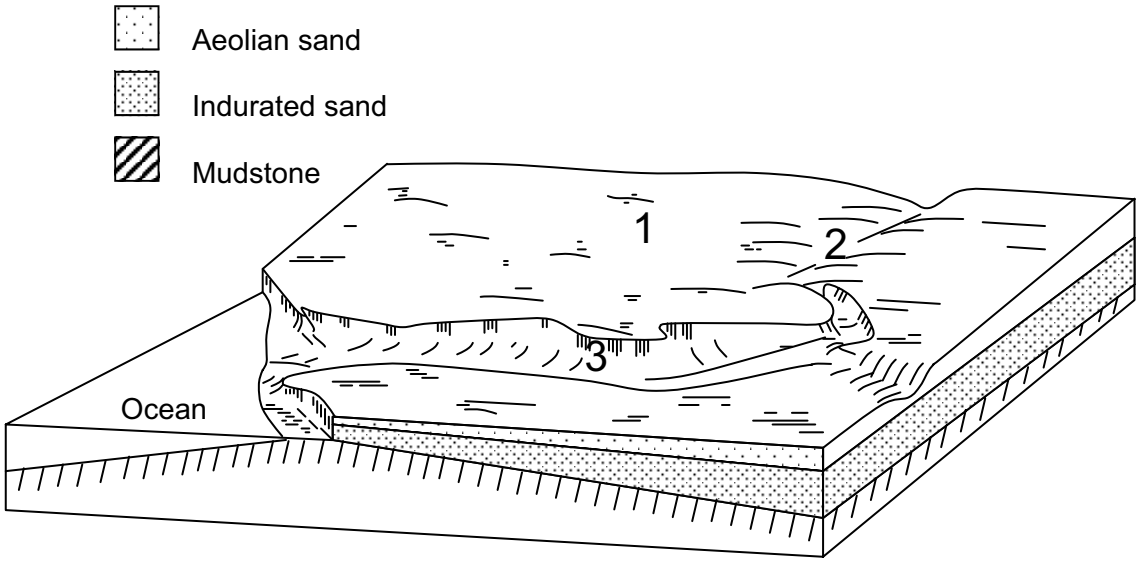
Geomorphology: Depositional sandplain adjacent to erosional surface of undulating laterite country with gullies draining to steep deeply incised coastal gullies and cliffs.

Location: Thangoo.

Pastoral use: A very low productivity system with Soft Spinifex (SOSP) pastures on units 1 and 2, and Samphire/Salt Water Couch (SASW) pastures on gully floors near the coast. Steep gully sides and cliffs are bare.

Estimated carrying capacity, good condition: 44 ha/cattle unit.

Range condition summary: Good 75%, fair 8%, poor 17% (1989–90).



Units and proportion of land system area

1.	Sandplains	70%
2.	Lateritic interfluves	16%
3.	Gullies and cliffs	14%

Gourdon land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Sandplains:** up to 7 km in extent and gently dipping to the west. (Gdn 1)	Earthy sands; dark red loamy sand topsoil over red loamy sand to coarse sandy loam subsoil; Uc 5.21.	Sparse low-tree steppe dominated by *Triodia pungens* with minor *Triodia bitextura* and *Chrysopogon fallax.* Trees dominated by *Corymbia setosa* and *Grevillea pyramidalis* and *Acacia* spp. shrubs. Pasture type: Soft Spinifex	Traversed; 2 site inventories.
2.	**Lateritic interfluves:** up to 1 km wide undulating interfluves and gullies with laterite and sandstone outcrop common. (Gdn 2)	Lithosols; lateritic gravels and rock outcrop with patchy thin sand cover.	Steppe grassland dominated by *Triodia pungens* with few *Grevillea* sp. aff*. angulata* shrubs. Pasture type: Soft Spinifex.	Traversed; 1 site inventory.
3.	**Gullies and cliffs:** up to 2.5 km long with steep sided gullies and cliffs opening westward onto coast; saline gully floors with tidal influence. (Gdn 3)	Lithosols and Solonchak; sandstone outcrop with consolidated Quaternary sands.	Little vegetation with some *Triodia pungens* on gully sides, and *Halosarcia* spp, *Sporobolus virginicus* and *Melaleuca acacioides* on gully floors. Pasture type: Samphire/Salt Water Couch.	Site visited.

GREAT SANDY LAND SYSTEM (1,919 km², 22.1% of survey area)

(after McKenzie 1985)

Extensive dunefields of linear dunes supporting spinifex grasslands with scattered shrubs and trees.

Geology: Quaternary aeolian sands.

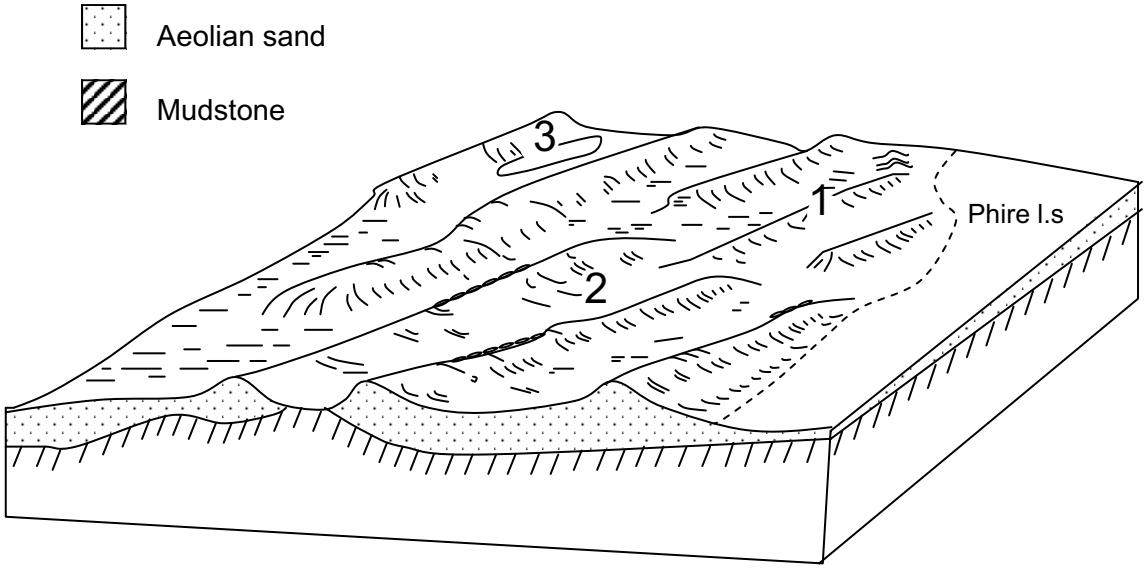
Geomorphology: Depositional surface; stable dune fields of longitudinal or seif dunes with swales opening locally onto sandplain or laterite outcrop plain; minor depressions receiving drainage with salt pans; relief up to 12 m.

Location: Nita Downs, Shamrock, unallocated Crown land.

Pastoral use: A very low productivity system with Soft Spinifex (SOSP) pastures. The dunes are stable and not prone to erosion.

Estimated carrying capacity, good condition: 60 ha/cattle unit.

Range condition summary: Good 91%, fair 3%, poor 6% (1989-90).



Units and proportion of land system area

1.	Dunes	30%
2.	Swales	68%
3.	Depressions with pans receiving run-on	2%

Great Sandy land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Dunes:** longitudinal ridges up to 12 m high and 40 km long with narrow crests and many small blowouts on the crests; flank slopes 25-45%. (Gsa 1)	Siliceous sands; red loose sand; Uc 1.23, Uc 1.22.	Sparse tree steppe dominated by *Triodia pungens* and *Triodia* sp. (feathertop spinifex) grasses; trees are dominated by *Corymbia setosa* and *Gardenia megasperma* with *Grevillea* and *Acacia* spp. shrubs. Pasture type: Soft Spinifex.	Traversed; 3 site inventories.
2.	**Swales:** from 0.5 to 1.0 km wide with flat floors and marginal slopes to 3%. Opening at western ends on to sandplain or laterite outcrop plains. Minor inclusions of laterite outcrop. (Gsa 2)	Earthy sands; dark reddish brown sand surface horizons overlying red loamy sand subsoils; Uc 5.21.	Sparse tree steppe dominated by *Triodia pungens* and *Triodia* sp. (feathertop spinifex) grasses; trees are dominated by *Corymbia setosa* and *Owenia reticulata* with *Acacia* spp. and *Grevillea* spp. shrubs. Pasture type: Soft Spinifex.	Traversed; 4 site inventories.
3.	**Depressions receiving run-on with pans:** salt pans with run-on areas extending up to 5 km either side; pans mostly 1-2 km in length but up to 4 km. (Gsa 3)	Earthy sands; brown silty clay surface horizon on brown sandy loam; surrounding soils are dark brown sandy loams overlying red to strong brown sandy loams to sands; Uc 5.22.	Pans bare: margins dominated by *Melaleuca acacioides, Acacia* and *Halosarcia* spp. shrubs plus *Xerochloa* spp. grasses; isolated *Eucalyptus* sp. (white gum).	Traversed; 2 site inventories. A few termite mounds present on sandy loam soils.

MANNERIE LAND SYSTEM* (85 km², 1.0% of survey area)
(after McKenzie 1985)

Seepage areas on inland margin of paleo-tidal coastal plain supporting thicket shrubland and halophytic vegetation.

Geology: Quaternary estuarine and littoral calcareous mud on alluvial sand.

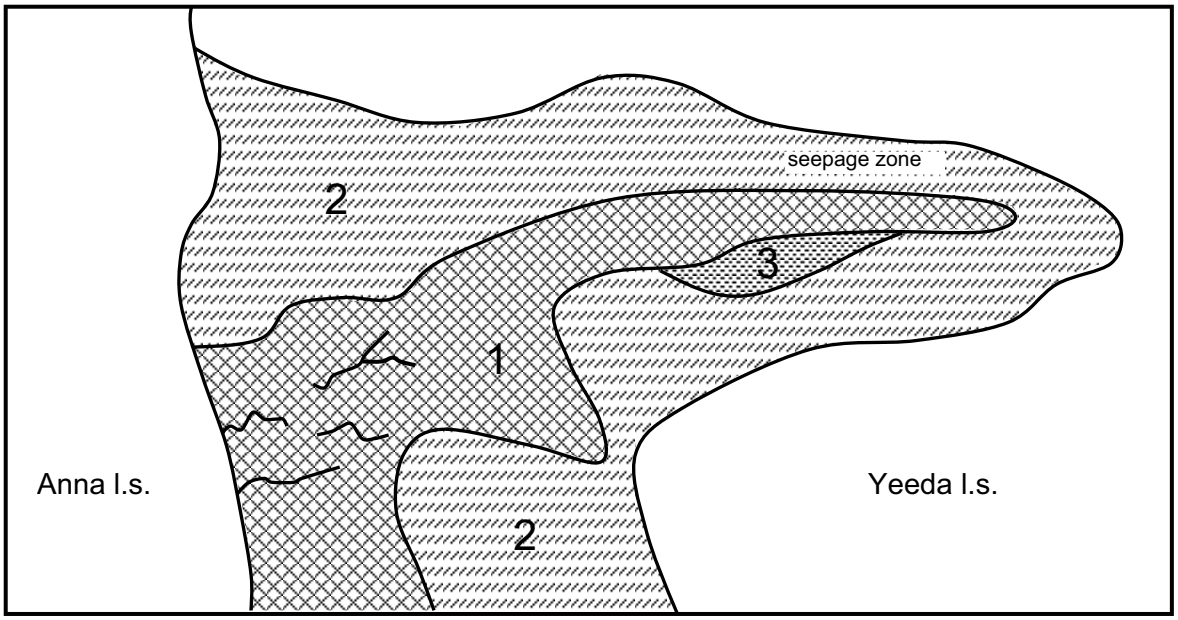
Geomorphology: Depositional surface; seepage zone between inland sandplain and coastal plain with tongue shaped areas extending up to 8 km into sandplain areas.

Location: Frazier Downs, Anna Plains.

Pastoral use: A moderately productive system with Samphire (SAMP) and Samphire/Salt Water Couch (SASW) pastures and minor Cenchrus (CENC) pastures.

Estimated carrying capacity, good condition: 19 ha/cattle unit.

Range condition summary: Good 47%, fair 43%, poor 10% (1989-90).



Units and proportion of land system area

1.	Samphire flats	45%
2.	Paperbark thickets	50%
3.	Saline depressions	5%

* The Mannerie land system has been redescribed by Van Vreeswyk *et al*. 2004.

Mannerie land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Samphire flats:** up to 3 km wide coastal plains with some internal drainage lines, 10 m above sea level. (Mnr 1)	Solonchak; grey silty clays; Uf 1.41.	Low shrubland dominated by *Halosarcia indica* ssp. *julacea* and *Halosarcia auriculata*, also *Halosarcia halocnemoides* and *Sporobolus virginicus.* Pasture types: Samphire and Samphire/Salt Water Couch.	Traversed; 1 site inventory.
2.	**Paperback thickets:** up to 3 km wide fringe of dense paperbarks around coastal plain margins; seepage zones. (Mnr 2)	Solonchak, brown sandy loam over yellowish sand, Uc 5.11; or greyish brown silty clay over grey silty sand, Dy 2.53; dusting of pinkish sand over surface.	Thicket shrubland dominated by *Melaleuca acacioides, Sporobolus virginicus* and *Halosarcia indica* ssp. *julacea.* Pasture types: Samphire/Salt Water Couch, Samphire and Cenchrus.	Traversed; 2 site inventories.
3.	**Saline depressions:** mainly bare plains between coastal plain and neighbouring inland sandplains.	Earthy sands; shallow sandy topsoil over cemented sands; dusting of pinkish sand over surface.	Mainly bare.	Traversed.

NITA LAND SYSTEM* (919 km², 10.6% of survey area)

(after McKenzie 1985)

Sandplain with deep red sands supporting sparse low-tree steppe grassland.

Geology: Quaternary aeolian sands.

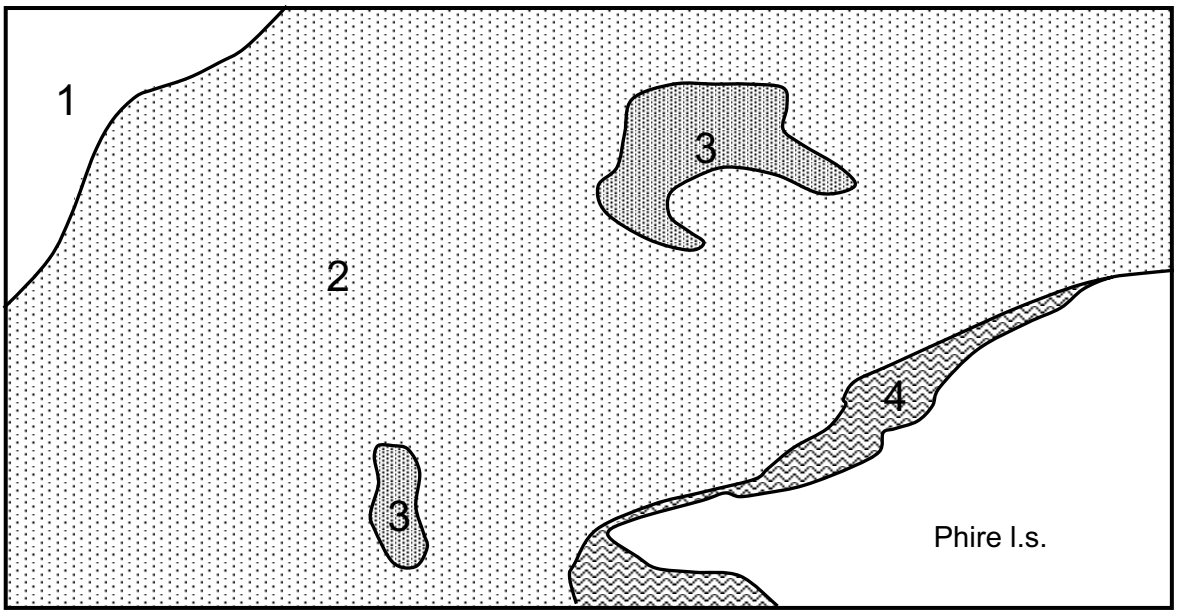
Geomorphology: Depositional surface of flat sandplain up to 20 km in extent. Little organised drainage but some marginal areas receiving run-on from neighbouring land systems.

Location: Frazier Downs, Nita Downs, Shelamar, Anna Plains, unallocated Crown land.

Pastoral use: A very low productivity system with Soft Spinifex (SOSP) pastures and minor Cenchrus (CENC) pastures; pastures require periodic burning followed by a deferral of grazing, to rejuvenate the spinifex and other grasses.

Estimated carrying capacity, good condition: 55 ha/cattle unit.

Range condition summary: Good 85%, fair 12%, poor 3% (1989-90).



Units and proportion of land system area

1.	Marginal sandplains	6%
2.	Sandplains	90%
3.+	Plains with thin sand cover	2%
4.+	Drainage floors	2%

\+ These units not present in original McKenzie (1985) description.

* The Nita land system has been redescribed by Van Vreeswyk *et al.* (2004).

Nita land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.*	**Marginal sandplains:** margin of sandplain with neighbouring coastal plain.	Earthy sands; red loamy sands; Uc 5.21	Savannah woodland dominated by *Bauhinia cunninghamii* and *Acacia translucens* with *Cenchrus ciliaris, Eragrostis eriopoda* and *Triodia pungens.* Pasture type: Cenchrus	Not sampled.
2.	**Sandplains:** mainly flat sandplain up to 20 km in extent. (Nit 2)	Earthy sands; dark reddish brown sand to loamy sand topsoil over red loamy coarse sand subsoil; Uc 5.21.	Sparse low-tree steppe dominated by *Triodia pungens* with some *Triodia* sp. (feathertop spinifex) and *Chrysopogon fallax.* Trees include *Corymbia*, *Grevillea* and *Hakea* spp. with shrubs dominated by *Acacia colei, A. translucens* and *A. orthocarpa.* Pasture type: Soft Spinifex.	Traversed; 9 site inventories.
3.	**Plains with thin sand cover:** up to 3 km wide and 1 km long flat plains; discontinuous sand mantles with laterite gravels in patches and isolated outcrops of laterite. (Nit 3)	Earthy sands; dark reddish brown sand topsoil over red loamy coarse sand subsoil; Uc 5.21.	Sparse low-tree steppe dominated by *Triodia pungens* and *Acacia lysiphloia.* Pasture type: Soft Spinifex.	Traversed; 1 site inventory.
4.	**Drainage floors:** up to 10 km long and 2 km wide strips receiving run-on from neighbouring lateritic land system. (Nit 4)	Earthy sands; dark reddish brown.	Tree savannah dominated by *Corymbia dichromophloia*	Traversed; 3 site inventories. Termite mounds.

* This unit described by McKenzie (1985) not sampled or mapped during this survey.

PARDA LAND SYSTEM (153 km², 1.8% of survey area)

Conical hills, stony ring plains, alluvial plains and shallow valleys supporting spinifex grassland with sparse shrubs and trees.

Geology: Mudstone of late Cretaceous age, shale or deeply weathered mudstone with sandstone cap rock; Quaternary sand, silt and minor gravel of alluvial origin.

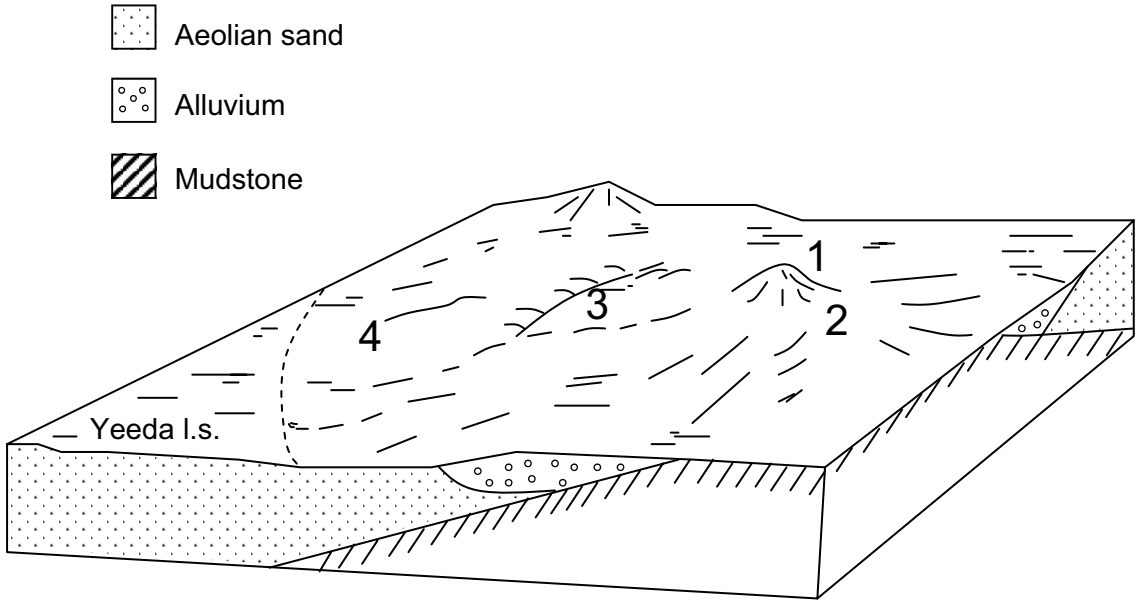
Geomorphology: Erosion remnant conical hills surrounded by stony surfaced ring plain with minor radial gullying; surrounded by alluvial floors and marginal sandplain. Relief up to 47 m.

Location: Shamrock, unallocated Crown land.

Pastoral use: A very low productivity system with Lobed Spinifex (LOSP), Oat-eared Spinifex/Ribbon Grass (OERG), Soft Spinifex (SOSP) and Ribbon Grass (RGRB) pasture types. This system is susceptible to water erosion if the soil surface is broken.

Estimated carrying capacity, good condition: 57 ha/cattle unit.

Range condition summary: Good 74%, fair 21%, poor 5% (1989-90).



Units and proportion of land system area

1.	Conical hills	1%
2.	Ring plains	32%
3.	Alluvial shallow plains	36%
4.	Shadow valleys	31%

Parda land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Conical hills:** up to 30 m high with moderately inclined slopes and stony surfaces. (Pda 1)	Red clays; red clay with stony surface mantle on mudstone; Uf 1.43.	Steppe grassland dominated by *Triodia intermedia* with scattered *Eucalyptus brevifolia.* Pasture type: Lobed Spinifex.	1 site inventory. Minor gully erosion.
2.	**Ring plains:** up to 6 km wide gently inclined plains with sandstone or shale stones as strew. (Pda 2)	Lithosols and red clays; reddish sandy loam or clay topsoil on red clay or gravels with stony surface mantle; Dr 2.32, Uf 1.43.	Steppe grassland dominated by *Triodia intermedia* with scattered *Acacia victoriae* and *Eucalyptus brevifolia.* Pasture type: Lobed Spinifex.	Traversed; 2 site inventories. Termite mounds.
3.	**Alluvial plains:** up to 3 km wide flat to very gently inclined plains. (Pda 3)	Alluvial soils; dark reddish or yellowish brown loamy topsoil over a brown or red loam to clay B horizon on laterite gravel; Um 5.51, Dr 2.32.	Pindan shrubland dominated by *Triodia pungens, Triodia schinzii* and *Chrysopogon fallax* with *Acacia eriopoda.* Pasture type: Oat-eared Spinifex/Ribbon Grass, Soft Spinifex and Lobed Spinifex.	Traversed; 2 site inventories. Termite mounds.
4.	**Shallow valleys:** up to 1 km wide very shallow valleys on margin with surrounding sandplains. (Pda 4)	Earthy sands; dark reddish brown sandy loam topsoil on red sandy loam subsoils; Um 5.52.	Tree savannah dominated by *Corymbia dichromophloia* with *Triodia pungens* and *Triodia schinzii.* Pasture types: Soft Spinifex and Oat-eared Spinifex/Ribbon Grass.	Traversed; 1 site inventory.

PHIRE LAND SYSTEM (474 km², 5.5% of survey area)

(after McKenzie 1985)

Outcrop plains with laterite gravels and low ridges supporting spinifex grasslands.

Geology: Minor sand and silt of mixed alluvial and aeolian origin over laterite on mudstone of late Cretaceous age.

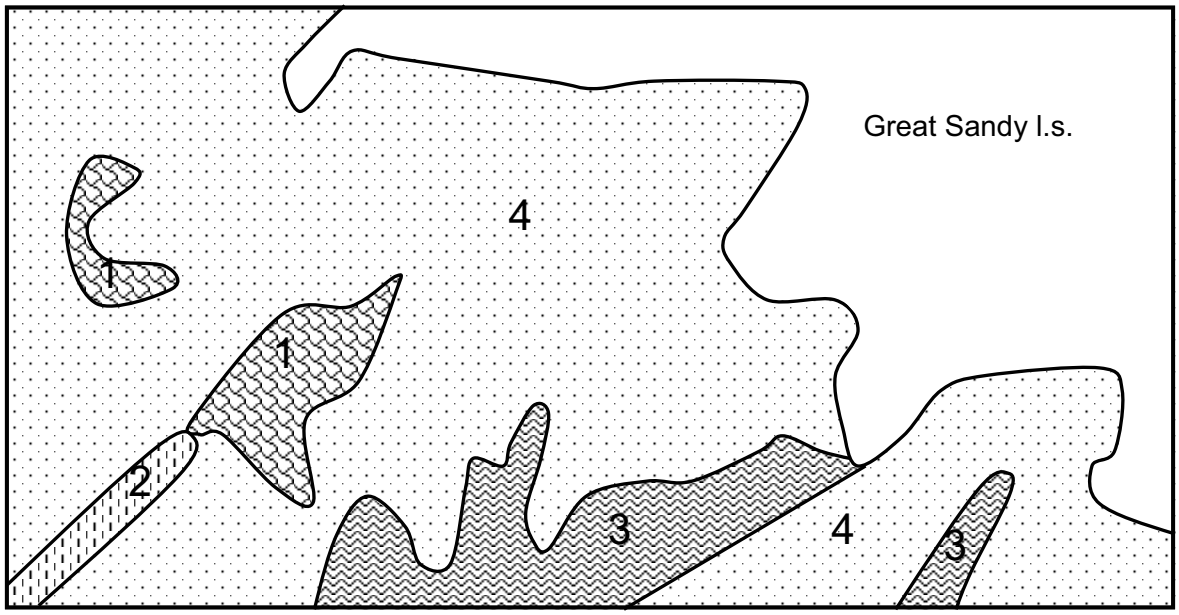
Geomorphology: Erosional surface of flat to gently undulating plains up to 10 km in extent. Organised surface drainage absent on flat plains with shallow depressions in undulating areas.

Location: Frazier Downs, Nita Downs, Shamrock, Anna Plains, unallocated Crown land.

Pastoral use: A very low productivity system with Soft Spinifex (SOSP) and Lobed Spinifex (LOSP) pastures. This system is fragile and susceptible to erosion when grazed.

Estimated carrying capacity, good condition: 57 ha/cattle unit.

Range condition summary: Good 66%, fair 16%, poor 18% (1989-90).



Units and proportion of land system area

1.*	Stony surfaces	8%
2.	Breakaways	1%
3.	Broad drainage floors	15%
4.	Lateritic plains with thin sand cover	76%

* This unit not present in original McKenzie (1985) description.

Phire land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Stony surfaces:** up to 1 km wide and 9 km long laterite outcrop on plains or low rises. (Phr 1)	Lithosols; thin layer of laterite gravels over laterite; KS UC 5.21.	Steppe grassland dominated by *Triodia intermedia* and minor *Triodia pungens* with isolated *Acacia translucens, A. victoriae* and *Grevillea pyramidalis.* Pasture type: Lobed Spinifex and Soft Spinifex.	Traversed; 1 site inventory.
2.	**Breakaways:** laterite or shale outcrop on mudstone base; up to 4 m relief, and up to 0.5 km wide and 2 km long. (Phr 2)	Lithosols.	Bare rock with some *Triodia intermedia.* Pasture type: Lobed Spinifex.	Sites visited.
3.	**Broad drainage floors:** gently sloping run-on areas adjacent to sandplain. (Phr 3)	Earthy sands; brown sand with laterite gravels below 70 cm, KS Uc 5.22.	Sparse pindan shrubland dominated by *Triodia pungens, Acacia eriopoda, A. colei* and *Eucalyptus* and *Corymbia* spp. Pasture type: Soft Spinifex.	Traversed; 1 site inventory.
4.	**Lateritic plains with thin sand cover:** flat plains up to 10 km in extent. (Phr 4)	Lithosols; less than 20 cm dark reddish brown sand on laterite gravels; KS Uc 5.21.	Steppe grassland dominated by *Triodia pungens* with scattered *Acacia translucens, A. orthocarpa* and *Grevillea* spp. Pasture type: Soft Spinifex.	Traversed; 6 site inventories. Low termite mounds.

ROEBUCK LAND SYSTEM (331 km², 3.8% of survey area)

(modified from Speck *et al.* 1964)

Paleo-tidal coastal plains and tidal flats with saline soils supporting halophytic low shrublands, melaleuca thickets and mangroves.

Geology: Quaternary estuarine and littoral calcareous mud and silty sand; aeolian sand and coral.

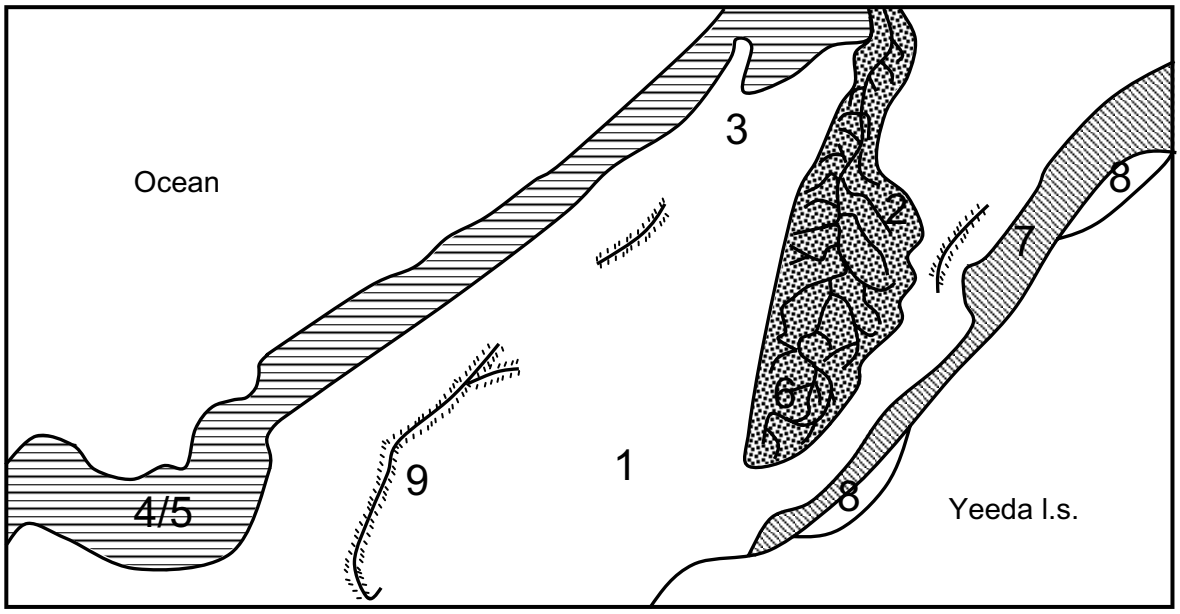
Geomorphology: Depositional surface of saline coastal flats. Landward margin of black coral with mangrove fringe along seaward margin, intervening samphire flats with intricately branching pattern of shallow tidal inlets in lower reaches; minor low fixed dunes.

Location: Frazier Downs, Thangoo.

Pastoral use: A low to moderately productive system with Samphire (SAMP) pastures. Samphire/Salt Water Couch (SASW) pastures occur as a 100-200 m wide strip on inland margin and in very small isolated areas on the plain. Littoral pastures (LITT) predominate on Unit 7 and Cenchrus (CENC) pastures on Unit 9. Unproductive mangroves occur along the seaward margin.

Estimated carrying capacity, good condition: 24 ha/cattle unit.

Range condition summary: Good 49%, fair 30%, poor 21% (1989-90).



Units and proportion of land system area

1.	Plains	56%
2.	Tidal samphire flats	13%
3.	Mud flats	5%
4.	Slopes at lower margins of mud flats/samphire flats	4%
5.	Outer flats	4%
6.	Channels	13%
7.*	Inner slopes	3%
8.*	Landward margins	2%
9.*	Dunes	< 1%

* These units not present in original Speck *et al*. (1964) description.

Roebuck land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Plains and samphire flats:** up to 10 km in extent and 5-6 m above sea level. (Roe 1)	Solonchak; light grey silty clays and minor fine sandy loams; Uf 1.41, Um 5.42, Uc 1.41.	Low shrubland and short bunch-grass savannah dominated by *Halosarcia indica* ssp. *julacea, Halosarcia halocnemoides* ssp. *tenuis* and *Sporobolus virginicus.* Pasture type: Samphire/Salt Water Couch.	Traversed; 5 site inventories. Minor inclusions of low dunes.
2.	**Tidal samphire flats:** up to 4 km wide; very shallow tidal lines inundated during spring tides. (Roe 2)	Solonchak; light grey silty clays.	Low shrubland dominated by *Halosarcia auriculata.* Pasture type: Samphire.	Traversed; 2 site inventories. Subject to moderate wind erosion when surface is broken.
3.*	**Mud flats**		No vegetation.	Not sampled.
4/5	**Slopes and outer flats at lower margin of mud flats/ samphire flats:** up to 1 km wide with many shallow channels and subject to tidal inundation. (Roe 4/5)	Solonchak; light grey silty clays; Uf 1.41.	Mangrove shrubland with low open mangrove community of *Avicennia marina*.	1 site inventory.
6.*	**Channels**			Not sampled.
7.	**Inner slopes:** up to 660 m wide along landward margin bordering Yeeda land system, 7-8 m above sea level. (Roe 7)	Solonchak; black silt overlying hard black or pale brown coral; Um 5.11, Gc 1.22, Dg 2.53.	Thicket shrubland dominated by *Melaleuca acacioides.* Pastures comprise *Sporobolus virginicus, Cynodon dactylon, Xerochloa* and *Scirpus* spp. Pasture type: Littoral.	Traversed; 3 site inventories.
8.	**Landward margins:** Bare flats up to 500 m wide and 5 km long. (Roe 8)	Earthy sands; yellowish brown loamy sand on coral; Uc 5.12.	Mainly bare with few scattered *Melaleuca acacioides,* minor *Sporobolus virginicus, Enneapogon polyphyllus* and Malvaceae herbs/low shrubs.	1 site inventory.
9.	**Dunes:** Linear, up to 3 km long and 2 m high. (Roe 9)	Calcareous sands; brown sand with surface darkened by organic matter; abundant shells.	Tussock grassland with shrubs dominated by *Cenchrus ciliaris* and *Acacia bivenosa.* Pasture type: Cenchrus.	Traversed; 3 site inventories. Stabilised.

* These units described by Speck *et al*. (1964) not sampled or mapped during this survey.

YEEDA LAND SYSTEM (4,468 km², 51.6% of survey area)

(after Speck *et al.* 1964)

Sandplain with deep red and yellow sands supporting pindan acacia shrublands and eucalypt woodlands.

Geology: Quaternary aeolian sands.

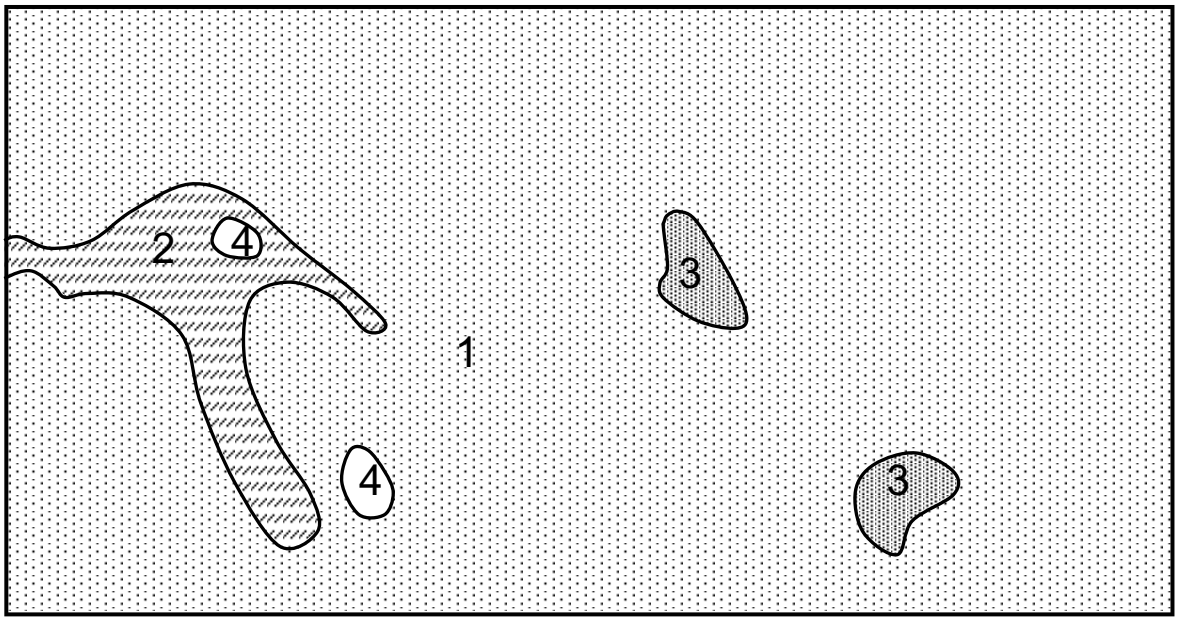
Geomorphology: Sandplain with little organised drainage, up to 16 km in extent, with shallow valleys, plains with thin sand cover, and scattered pans, with limited surface drainage in zones of sheet-flow up to 3 km wide and extending up to 8 km downslope from adjacent uplands.

Location: Frazier Downs, Nita Downs, Shamrock, Shelamar, Thangoo, unallocated Crown land.

Pastoral use: A very low productivity system with Soft Spinifex (SOSP), Oat-eared Spinifex/Ribbon Grass (OERG), Cenchrus (CENC) and Ribbon Grass (RGRB) pastures. This system is not prone to erosion due to stabilising pindan vegetation.

Estimated carrying capacity, good condition: 47 ha/cattle unit.

Range condition summary: Good 58%, fair 23%, poor 19% (1989-90).



Units and proportion of land system area

1.	Sandplains	82%
2.	Shallow valleys	14%
3.	Plains with thin sand cover	3%
4.	Pans	1%

Yeeda land system

Unit	Landform and map symbol	Soil	Vegetation	Comments
1.	**Sandplains:** up to 16 km in extent with slopes less than 1%; infrequent rocky hills less than 30 m high with boulder strewn slopes up to 60%. (Yed 1)	Earthy sands; dark reddish brown loamy sand or dark red sand topsoil over red sand to coarse sandy loam subsoils; Uc 5.21.	Pindan shrubland dominated by *Acacia eriopoda, A.colei, Bauhinia cunninghamii, Corymbia dichromophloia* and *Grevillea* spp. with *Triodia pungens* and *T*. sp. *Melaleuca acacioides* where sandplains border the coastal plains. Pasture types: Soft Spinifex, Oat-eared Spinifex/Ribbon Grass.	Traversed; 27 site inventories. A few termite mounds on soil with sandy loam subsoil.
2.	**Shallow valleys:** up to 5 km wide with gently undulating floors and slopes up to 3%. (Yed 2)	Earthy sands; dark reddish brown loamy sand topsoil over red loamy sand subsoils; Uc 5.21.	Pindan shrubland dominated by *Eucalyptus grandifolia, Bauhinia cunninghamii* and *Acacia* spp. shrubs with *Triodia pungens, T.* sp., *Chrysopogon fallax* and *Cenchrus ciliaris.* Pasture types: Soft Spinifex, Oat-eared Spinifex/Ribbon Grass and Cenchrus	Traversed; 16 site inventories. A few termite mounds.
3.	**Plains with thin sand cover:** up to 3 km wide discontinuous sand mantles with pebble patches and isolated rocky hills less than 30 m high with boulder strewn slopes. (Yed 3)	Earthy sands and lithosols; dark reddish brown loamy sand topsoil over red sand to loamy sands; Few profiles consisting of laterite gravels; Uc 5.21, KS Uc 5.21.	Pindan shrubland dominated by *Acacia lysiphloia* and *A. eriopoda* with *Triodia pungens, T.* sp. and *Chrysopogon fallax*. Pasture types: Soft Spinifex, Oat-eared Spinifex/Ribbon Grass.	Traversed; 6 site inventories. A few termite mounds.
4.*	**Pans:** less than 0.8 km wide and 1.5 m deep with short marginal slopes and cracking surfaces.	Brownish, massive, intractable, silty to heavy clays.	Various tall grasses with fringes of *Corymbia polycarpa* and *Melaleuca* spp.	Not sampled.

* This unit described by Speck *et al*. (1964) not sampled or mapped during this survey.

Soils

The only published works on soils of this area are by McArthur *et al.* (1967) and Stace *et al.* (1968) who mapped the area at 1:2,000,000 and 1:10,000,000 scales respectively. Similar soils were described in a land system survey by Speck *et al.* (1964) over areas to the north and north-east of this survey area.

Mapping units used in this survey were land units and it was found that similar soils occurred over several different land units and sometimes more than one soil type occurred within land units.

To characterise the soils and their patterns of distribution across each type of landscape in more detail, soil descriptions were routinely taken at inventory points during the course of the survey.

The soils were classified according to Principal Profile Form (Northcote 1979), Great Soil Group (Stace *et al.* 1968), Australian Soil Classification (Isbell 2002) and the Soil Groups of Western Australia (Schoknecht 2002). No attempt was made to assign soil types or names to the different soils apart from those names already published by Speck *et al.* (1964), as shown in Table 11.

Representative soil profile descriptions are included in Appendix 2.

Soils of the Kimberley Surface

Shallow coarse textured soils (KS Uc 5.21, KS Uc 5.22) are the most common (75%) in this district. These soils have less than 20 cm of dark reddish brown sand and overlie yellowish red laterite gravels with a minor clay matrix. Low termite mounds are common on soils with a matrix. These soils occur on laterite plains, broad drainage floors and stony surfaces of the Phire land system. In areas near the Great Sandy land system the sand overlying laterite trends to red. In areas south of Mt Phire and in areas near the Yeeda land system, the sand can be up to 40 cm deep and overlie laterite. Near Willara hill laterite gravels occurred at a depth of 0.5 to 1.0 m. These gravels overlie brown clay derived from strongly weathered shale or mudstone.

The shallow sands in this district are considered to be inherently fragile. Significant degradation of the spinifex pastures has occurred but little erosion was recorded. However, should cattle be introduced to these areas, the risk of degradation may become severe within a few years. Uncontrolled cattle grazing would reduce vegetation cover. Combined with the poor water storage and lack of deep moisture percolation of the soil, water erosion resulting in large scalded areas of bare laterite may be induced.

Medium textured uniform soils (Um 5.5, 5.51) cover 12 per cent of the Kimberley surface and occur on alluvial plains and shallow valleys of the Parda land system. Alluvial soils are brown sandy loams and silt loams overlying laterite gravels. Earthy sands are red sandy loams occurring at the boundary between the laterite and alluvial plains of the Parda land system and the surrounding sandplain of the Yeeda land system. These soils receive considerable run-off from the Parda land system and support thick stands of bloodwood trees (*Corymbia* spp.).

Fine textured uniform soils (Uf 1.43) are red clays overlying gravels at 20-70 cm depth. These soils support coarse (2-8 cm) surface mantles of sandstone or shale and occur on the conical hills, ring plains and alluvial plains of the Parda land system.

Skeletal soils, or soils composed of stones and larger rock fragments, occur on breakaways and hills of the Phire and Bulka land systems respectively. These soils have only minor amounts of sand matrix between rock fragments and support sparse lobed spinifex (*Triodia intermedia*) pastures.

Soils of the Sandplain

Uniform coarse textured soils (Uc 5.21, 5.22, 5.23) cover more than 99 per cent of this geomorphic district occurring on the Yeeda, Nita and Gourdon land systems.

Profiles consist of a very thin surface dusting of red loose sand overlying a very weak sandy loam surface crust. The main topsoil horizon is dark reddish brown sand with moderately weak consistence when dry. The subsoil horizon is red medium and coarse sand overlying red loamy coarse sandy horizons. The soils have an earthy to single grained fabric and a moderately firm consistence when dry. Structure is massive to weakly blocky. These soils have been identified as the Cockatoo and Yabbagoody family (Speck *et al.* 1964). Soils of the Cockatoo family are sands with loamy sand subsoils. Soils of the Yabbagoody family differ in that they have sandy loam subsoils.

Soils in depressions or valley floors of the Yeeda land systems are browner than those of the sandplain with topsoil horizons having 5YR or 10R hues (Munsell 1954) rather than the more common reddish 2.5YR hue.

Soils of the Kalyeeda family are dark brown (10YR hue) sands whilst those of the Tableland family are sands over mottled subsoils. These soils are well drained, rapidly permeable and are not subject to water erosion. The soils supporting spinifex pastures, contain few if any weathered materials and are deficient in phosphorous. They have low water holding capacities and so would need frequent irrigation if used for crop production. Roads formed on these soils are firm and stable.

Soils of the Dune Fields

Uniform coarse textured soils (Uc 5.21) occur throughout the Dune Fields geomorphic district. Red earthy sands of the Cockatoo family predominate over the interdune swales of the Great Sandy land system covering approximately 62 per cent of the area. Red siliceous sands (Uc 1.22, 1.23) occur on the dune ridges and cover approximately 36 per cent of the Great Sandy land system. The siliceous sands have loose consistence and single grain structure.

The vegetation is soft spinifex (*Triodia pungens*) or feathertop spinifex (*Triodia* sp.) with pindan type woodland. The siliceous sands are subject to wind erosion when vegetative cover is removed by fire or grazing animals.

Minor areas (2%) of the Great Sandy land system consists of brown coloured soils in bare pan areas. These have a silty clay surface horizon overlying sand and are saline. Pan areas are internal drainage accumulation zones. The centres of the pans have bare surfaces and the perimeters support salt tolerant vegetation.

Soils of the Coastal Dunes

Uniform coarse textured soils (Uc 1.11, 1.21) cover the coastal dunes. The soils are loose light grey to light yellowish brown siliceous and calcareous sands. They are apedal with single grain structure. The siliceous sands are free of coarse fragments whereas the calcareous sands contain abundant shells or shell fragments. These soils occur on the Eighty Mile land system. The vegetation is tussock grass or spinifex with occasional shrubs.

Soils of the Coastal Plain

This district is dominated by uniform fine (Uf 1, Uf 6) and medium (Um 5) textured soils which occur on the flat paleo-tidal coastal plain.

The soils are mostly silty clays with some sandy clay loams and fine sandy loams. Soils of the Roebuck land system have light grey to brownish grey surface horizons whereas soils of the Anna land system have black topsoil horizons from 13-22 cm thick. Subsoils are all light grey in colour. These fine textured soils have very firm consistence when moist and become very strong when dry. Soil surfaces may be powdery when dry but become slippery and not traversable when wet. These soils support salt tolerant vegetation such as salt water couch (S*porobolus virginicus)* on less saline areas and samphires *(Halosarcia* spp.) on more saline sites.

Black silt soils, overlying coral, occur on the inland margins of the Roebuck land system. These soil surfaces may also be powdery when dry and slippery when wet. They are dominated by coastal paperbarks *(Melaleuca acacioides*).

Uniform coarse textured soils (Uc 5.11) occur in seepage areas between the coastal plain and inland sandplain (Mannerie land system, Unit 2) and on low relief dunes (Uc 1.11) in the Roebuck land system (Unit 9). The dunes are 1-2 m high and support buffel grass *(Cenchrus ciliaris)*.

Gradational (Gc 1.22) and duplex (Dg 2.53, Dy 2.53) soils are a minor component of this district. They occur on the inland margins of the coastal plain where soil parent materials are mixed resulting in non-uniform textures down the profile.

Table 11. Classification of soils in part of Broome Shire

	Principal profile form	Equivalent soil family*	Great soil group	Land units
Soils of the Kimberley Surface				
Uniform - coarse textured soils	KS - Uc 5.21	-	Lithosols	Phr 1, Phr 4
	KS - Uc 5.22	-	Lithosols	Buk 2
	-	Tableland	Earthy Sands	Phr 3
- medium textured soils	Um 5.51	Robinson	Alluvial Soils	Pda 3
	Um 5.5	Yabbagoddy	Earthy Sands	Pda 4
- fine textured soils	Uf 1.43	Moonah	Red Clays	Pda 1
	-	-	Lithosols	Pda 2
Duplex soils	Dr 2.23	Moonah	Red Clays	Pda 2, Pda 3
Skeletal soils	-	-	Lithosols	Buk 1, Phr 2
Soils of the Sandplains				
Uniform - coarse textured soils	Uc 5.21	Cockatoo	Earthy Sands	Gdn 1, Nit 2, Nit 3, Yed 1, Yed 2, Yed 3
	-	Yabbagoody	Earthy Sands	Gdn 1, Nit 4, Yed 1, Yed 2, Yed 3
	KS - Uc 5.21	-	Lithosols	Yed 3
Skeletal soils	-	-	Lithosols	Gdn 2
Soils of the Dune Fields				
Uniform - coarse textured soils	Uc 1.22, 1.23	Cockatoo	Siliceous Sands	Gsa 1
	Uc 5.21	Cockatoo	Earthy Sands	Gsa 2
	-	Yabbagoody	Earthy Sands	Gsa 2
	Uc 5.22	Kalyeeda	Earthy Sands	Gsa 3
	-	Tableland	Earthy Sands	Gsa 3
Soils of the Coastal Dunes				
Uniform - coarse textured soils	Uc 1.11	Beach dune complex	Calcareous Sands	Roe 9
	Uc 1.21	Beach dune complex	Siliceous Sands	Eig 1, Eig 3
Soils of the Coastal Plains				
Uniform - coarse textured soils	Uc 1.41	Samphire soils	Solonchak	Roe 1
	Uc 5.11	-	Solonchak	Mnr 2
	Uc 5.12	-	Earthy Sands	Roe 8
- medium textured soils	Um 5.11	Samphire soils	Solonchak	Roe 7
	Um 5.42	Samphire soils	Solonchak	Roe 1
- fine textured soils	Uf 1.41	Dark saline muds	Solonchak	Roe 4 and 5
	-	Samphire soils	Solonchak	Roe 1, Roe 2, Mnr 1
	Uf 6.51	Salt flat soils	Solonchak	Ann 1, Ann 2
Gradational soils	Gc 1.22	Samphire soils	Solonchak	Roe 7
Duplex soils	Dg 2.53	Samphire soils	Solonchak	Roe 7
	Dy 2.53	Samphire soils	Solonchak	Mnr 2

* Speck *et al*. (1964).

Pasture types

Within the 14 land systems mapped, there are a number of basic vegetation alliances that can be recognised as broad pasture types. Ten pasture types have been described, each type tending to develop whenever the geomorphology, soil type, hydrology and climatic influences are very similar. The pasture type is not strictly a botanical classification, because, in determining such a class of pastoral lands the perennial plant species that contribute to stock production have an over-riding importance. Even so, each pasture type can be said to represent a broad working group of similar vegetation associations.

The total area of the 10 described pasture types and the areas of mangrove communities (undescribed), unvegetated pans and bare mud flats are presented in Table 12.

The distribution of each pasture type is given on a land system basis. The composition of each pasture type is described in terms of the dominant species present with a complete species list included. Plant species are listed under the headings of desirable, intermediate and undesirable species. The relative desirability of each species was decided primarily on its forage value but other considerations, such as durability, were taken into account. Pasture condition was assessed, to a large extent, on the percentage of total plant cover comprised by each of the three groups of desirable, intermediate and undesirable species.

Maintenance of perennial plant species is essential as these provide the base for range stability and supply the bulk of feed for stock. Pastures that are degraded to annuals only supply short-term feed and by mid-year or earlier their grazing capacity is exhausted. Management should be aimed at encouraging the return and maintenance of desirable perennial species.

Pastoral values are given along with relevant management procedures.

Brief notes are included under condition statements on the key parameters used to assess pasture condition for those pastures not previously described. Reference should be made to Payne, Kubicki and Wilcox (1974) for the pasture types Littoral, Lobed Spinifex, Ribbon Grass, Soft Spinifex and Curly Spinifex – Ribbon Grass and for descriptions of parameters used in assessing pasture condition. The condition of each pasture type on each station was assessed during traverse as described in the section on Survey methods.

Detailed descriptions of each pasture type, compiled from observations and measurements made at inventory sites and at each 1 km traverse interval, are presented below, in order of decreasing area.

Table 12. Summary of pasture type areas (excluding Anna Plains station)

Pasture type	Area (km²)	%
Soft Spinifex (SOSP)	5,887	68.0
Oat eared Spinifex/Ribbon Grass (OERG)	1,803	20.8
Samphire/ Salt Water Couch (SASW)	324	3.7
Cenchrus (CENC)	217	2.5
Samphire (SAMP)	129	1.5
Lobed Spinifex (LOSP)	113	1.3
Coastal Dune (CSDN)	53	0.6
Oat-eared Spinifex (OESP)	19	0.2
Littoral (LITT)	14	0.2
Ribbon grass (RGRB)	13	0.1
Bare mud flats	47	0.5
Mangroves (undescribed)	26	0.3
Unvegetated pans	19	0.2
Total	**8,664**	**100.0**

Soft Spinifex pasture type (SOSP)* 5,887 km²

Distribution and soil types

The Soft Spinifex pasture type is the largest and most widely distributed within the survey area. It covers large areas of the sandplain land systems - Yeeda, Nita, Great Sandy and Gourdon. Smaller areas are found on alluvial units of the Parda land system, lateritic surfaces of the Phire land system and some sandplains of the Bulka land system. It covers a smaller area than Oat-eared Spinifex/Ribbon Grass pastures in the north of the survey area on Thangoo station but in the southern and eastern portions of Thangoo as well as on other sandplain areas of the rest of the survey area, Soft Spinifex pastures predominate.

The predominant soil types are red earthy sands on sandplains and in the swales between dunes of the Great Sandy land system. Siliceous sands occur on the dunes of the Great Sandy land system whilst lithosols predominate on the Phire land system and a minor amount of alluvial soils on the Parda land system.

Composition

Triodia pungens (soft spinifex) is the dominant perennial and often dominates the pasture to the virtual exclusion of other grasses. *Triodia* sp. (feathertop spinifex) occurs in some areas whilst other perennials such as *Chrysopogon fallax* (ribbon grass), *Triodia schinzii* (oat-eared spinifex) and *Sorghum plumosum* (perennial sorghum) are present, but only as minor components of the pasture. On the Great Sandy land system *Triodia* sp. (feathertop spinifex) dominates the pasture over approximately one-third of the area whilst *Triodia pungens* (soft spinifex) dominates over two thirds.

The undesirable perennials *Aristida holathera* (erect kerosene grass), *A. inaequiglumis* (feathertop threeawn) and the intermediate *Eriachne obtusa* (wiregrass) are present in minor amounts. The annual grass *Aristida hygrometrica* (corkscrew) is rare.

Trees and shrubs often form quite dense woodland/shrubland. *Acacia eriopoda* (Broome pindan wattle), *A. colei* (candelbra wattle), *Corymbia dichromophloia* (variable-barked bloodwood) and *Corymbia setosa* (rough-leaf bloodwood) are the most common species with *Acacia lysiphloia* (turpentine wattle) being abundant on land unit 3 of the Yeeda land system, where the soil is high in laterite gravel or near sandstone outcrop. *Eucalyptus grandifolia* (cabbage gum) is characteristic on land unit 2 of the Yeeda land system, and *Melaleuca acacioides* (paperbark) on sandplains of the Yeeda system where they border the coastal plains. Many other species also occur.

Pastoral value

Soft Spinifex pastures have a moderate grazing value but carrying capacity is low. They are readily accessible throughout the year and are capable of being utilised on a year-long basis. They are generally grazed by stock at all stages of growth, but young growth and flowering culms are more favoured (Photos 1 and 2). Palatability decreases with maturity but the plants remain green and are utilised as subsistence fodder. Cattle appear to prefer *Triodia pungens* (soft spinifex) over *Triodia* sp. (feathertop spinifex).

Soft spinifex is drought resistant and regarded as a useful drought reserve. In drought years utilisation may reach 50 per cent by weight, or more. During more normal seasons stock graze the few associated grasses and forbs, so that 20-30 per cent utilisation of the *Triodia pungens* could be expected.

In other rangeland areas controlled burning has been a useful tool for the maintenance of spinifex pastures in an attractive condition for stock. It clears old closed stands of spinifex, encouraging fresh growth plus the growth of annual grasses and forbs. However, the combined effect of fire and grazing on these Kimberley pastures is not well understood and is believed to lead to

* Equivalent to Soft Spinifex Pastures (SSPP) of Pasture types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

pasture degradation in some situations. If fire is used, burns should not be more frequent than about every five or six years as they can stimulate undesirable pasture species and result in thick regrowth of the pindan wattles. Burning should be carried out late in the dry season followed by a wet season spell from grazing.

Pastures in poor condition require spelling every second or third year over the wet season to allow recovery.

There is virtually no surface water on the large areas of sandplain and dunefields in this survey area. Consequently, cattle can be controlled on the spinifex-based pastures by self-mustering systems using spear gates and trap yards on man-made water points.

Condition statements

Those presented by Payne, Kubicki and Wilcox (1974) as summarised below were used in this survey.

- **Good to very good**

In this condition *Triodia pungens* is the dominant perennial and forms 80-90 per cent by weight, of the stand. Density and hummock size is usually uniform on any site, but varies between sites (hummocks 0.3-1.0 m wide and 0.5-1.5 m apart). Plants are vigorous and productive.

The density of other grasses and forbs in the stand is variable and dependent on seasonal conditions, grazing pressure and time of the year. In most cases they form sparse ground cover between the spinifex hummocks. Undesirable species such as *Aristida holathera*, *A. inaequiglumis*, *A. hygrometrica* and *Crotalaria crispata* are sparse and contribute little to the overall stand.

Triodia pungens and *T. bitextura* may show evidence of light use. More palatable species such as *Chrysopogon fallax* and *Enneapogon polyphyllus* are utilised more heavily but are still vigorous.

When in good to very good condition, no erosion is encountered on Soft Spinifex pasture lands.

- **Fair**

In fair condition the stand is patchy but *Triodia pungens* is still dominant and may form 60-70 per cent by weight of the total pasture. Vigour of the plants is moderate. Other desirables such as *Chrysopogon fallax* are occasionally present. The intermediate value perennials *Eragrostis eriopoda* and *Eriachne obtusa* can constitute 20 per cent of the pasture. The undesirable species *Aristida holathera, A. inaequiglumis* and *A. hygrometrica* increase in abundance, but these would still constitute less than a quarter of the stand. Weedy species such as *Crotalaria crispata*, *Waltheria indica, Cleome viscosa* and *Senna notabilis* marginally increase their proportions in the stand. Other annual grasses and forbs are rare.

On Soft Spinifex country in fair condition there is virtually no erosion. There may be some bare sandy patches 5-10 m in diameter and occasional minor wind erosion as very small, isolated scalds.

- **Poor to very poor**

When in this condition *Triodia pungens* still forms 30-40 per cent of the stand, but is patchy and the hummocks are well spaced (10-30 m apart). They may be heavily utilised and show poor-moderate vigour. Other desirable perennials are virtually absent or present only as weak and moribund butts.

The pasture tends to be dominated by the intermediate value perennial *Eriachne obtusa* and the undesirables *Aristida holathera, A. inaequiglumis* and *A. hygrometrica.* Undesirable weedy species are common but, collectively, still usually occupy less than a quarter of the stand. The total pasture stand is patchy and sparse and ground cover is poor.

There may be frequent small and medium size (5-10 m in diameter) almost bare sandy patches.

In this condition the overall erosion situation encountered is minor. On the margins of Soft Spinifex pastures near frontage country, there may be thin sheeting and rilling by water. Small isolated wind scalds and minor hummocking are sometimes present.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Cymbopogon procerus*	*Aristida holathera*
Cenchrus setigerus	*Eragrostis eriopoda*	*Aristida inaequiglumis*
Chrysopogon fallax	*Eragrostis desertorum*	
Sorghum plumosum	*Eragrostis setifolia*	
Triodia bitextura	*Eriachne obtusa*	
Triodia pungens		
Triodia schinzii		
Triodia sp.		
Annual grasses		
	Sorghum stipoideum	*Aristida hygrometrica*
	Xerochloa laniflora	*Aristida contorta*
		Eriachne ciliata
Miscellaneous species		
Aerva javanica	*Corchorus sidoides*	*Acacia translucens*
	Malvaceae herbs/low shrubs	*Senna notabilis*
		Trichodesma zeylanicum

Trees and shrubs

Acacia ampliceps
Acacia ancistrocarpa
Acacia drepanocarpa
Acacia eriopoda
Acacia hilliana
Acacia colei
Acacia lysiphloia
Acacia victoriae
Atalaya hemiglauca
Bauhinia cunninghamii
Brachychiton viscidula
Buchanania obovata
Carissa lanceolata
Corymbia dichromophloia
Corymbia ferruginea
Corymbia setosa
Dolichandrone heterophylla
Eucalyptus brevifolia
Eucalyptus grandifolia
Gardenia megasperma
Grevillea agrifolia
Grevillea erythroclada
Grevillea pyramidalis
Grevillea refracta
Grevillea sp. aff. *angulata*
Grevillea striata
Gyrocarpus americanus
Hakea lorea
Melaleuca acacioides
Owenia reticulata
Flueggea virosa
Ventilago viminalis

Photo 1. Soft spinifex (SOSP) pasture type in very good condition, Yeeda land system, Thangoo station. Soft spinifex (*Triodia pungens*) with pindan shrubland dominated by Broome pindan wattle (*Acacia eriopoda*) and variable-barked bloodwood (*Corymbia dichromophloia*).

Photo 2. Soft Spinifex (SOSP) pasture type in good condition, swale of Great Sandy land system, Nita Downs. Soft spinifex (*Triodia pungens*) and feathertop spinifex (*Triodia* sp.) in mature rank condition are not as palatable to stock as short fresh growth. Note the distant dune ridge with shrubs present but minimal pasture cover making it susceptible to erosion.

Oat-eared Spinifex/Ribbon Grass pasture type (OERG)* 1,803 km²

Distribution and soil types

The Oat-eared Spinifex/Ribbon Grass pasture type occurs on areas of the sandplain ("pindan") country; predominantly on the Yeeda land system. Smaller areas occur on alluvial units of the Parda land system. This pasture type predominates on sandplain areas in the northern half of the survey area with other sandplain pastures occurring in association but being sub-dominant, i.e. Soft Spinifex (SOSP), Oat-eared Spinifex (OESP) and Ribbon Grass (RGRB). Towards the southern end of Thangoo station and on Frazier Downs and Nita Downs, Soft Spinifex pastures assume dominance over Oat-eared Spinifex based pastures.

The predominant soil type is red earthy sands on the sandplain with only minor amounts of alluvial soil on the Parda land system.

Composition

Triodia schinzii (oat-eared spinifex) is the dominant perennial with *Chrysopogon fallax* (ribbon grass) occurring in variable amounts. The ribbon grass appears to occur mainly around the base of trees, probably due to greater fertility from leaf fall.

The perennials *Triodia pungens* (soft spinifex), *Sorghum plumosum* (perennial sorghum), *Eriachne obtusa* (wiregrass), *Aristida inaequiglumis* (feather top threeawn) and *Aristida holathera* (erect kerosene grass) are present. Minor amounts of *Triodia bitextura* (curly spinifex) and *Eragrostis eriopoda* (woollybutt) are also present. The intermediate species *Corchorus sidoides* (flannel weed), and undesirable *Crotalaria crispata* (Kimberley horse poison) are present in minor amounts.

Trees and shrubs often make up a fairly dense canopy cover known as pindan. Dominant species include *Acacia eriopoda* (Broome pindan wattle), *A. colei* (candelbra wattle), *Bauhinia cunninghamii* (bauhinia), *Corymbia dichromophloia* (variable-barked bloodwood) and *Carissa lanceolata* (conkerberry).

Where the soil has a lateritic gravel component or in areas near sandstone outcrop, *Acacia lysiphloia* (turpentine wattle) predominates in the upper storey, i.e. on unit 3 of the Yeeda land system. On unit 2 of the Yeeda land system *Eucalyptus grandifolia* (cabbage gum) is characteristic. Many other tree and shrub species also occur.

Pastoral value

The pastoral value of this pindan country is variable, but generally it has a low carrying capacity (Photos 3 and 4). During and immediately after the wet season it supplies reasonably good quality feed but quality is poor later in the year. Pindan country is accessible throughout the year.

Condition statements

This pasture type corresponds to the Curly Spinifex-Ribbon Grass pasture land described by Payne, Kubicki and Wilcox (1974) in areas to the north-east of this survey area. *Triodia schinzii* replaces *T. bitextura* in this survey area as the predominate perennial but apart from this change the condition guides for Curly Spinifex-Ribbon Grass pasture land were used and are summarised below.

- **Good to very good**

Triodia bitextura and *Chrysopogon fallax* are the predominant perennials of this pasture land when it is in good condition.

Triodia bitextura is the dominant species and may make up to 50 per cent or more by weight of the total stand. The distribution of *Triodia* is uniform, but of variable density depending on the site. Large sandplains and interdunal areas carry dense stands (0.5-1.5 m between plants). On drier sites, such as dune tops, the *Triodia* stands may still be reasonably uniform but the density is lower (1-3 m between plants).

* Equivalent to Curly Spinifex Plain Pastures (CSPP) and Ribbon Grass Pastures (RGRP) of Pasture Types of the Kimberley – definitive list as at the 31 March 2004 (Unpublished, WADA Kununurra).

The ground space between the curly spinifex and ribbon grass tussocks has a sparse cover of other perennials such as *Eragrostis eriopoda, Eriachne obtusa* and *Sorghum plumosum* and numerous annual grasses and forbs.

In good condition, vigour and production of the desirable species are good. Seedlings and young plants of curly spinifex and ribbon grass are usually present.

The most useful species for stock are *Chrysopogon fallax*, *Sorghum plumosum* and the annual *Panicum* and *Enneapogon* spp. Many of the short-lived forbs are also palatable and nutritious. Curly spinifex is considered mainly as a drought reserve and its attractiveness to stock declines with age.

Periodic controlled burning can induce a desirable sub-climax situation on pindan pastures. In this situation the annual grasses and forbs component of the pasture increases considerably. There should also be numerous small curly spinifex seedlings present which at this stage of growth are readily palatable to stock. After three or four years curly spinifex resumes dominance.

Provided there is not a dominance of undesirable annual grasses and weedy forbs, pindan pastures in the sub-climax situation can be regarded as good or very good condition. However, too frequent uncontrolled burning induces dominance of undesirables such as *Aristida inaequiglumis, A. hygrometrica, Velleia panduriformis* (pindan poison), *Senna notabilis* (cockroach bush), *Crotalaria crispata* and *Solanum* spp. Desirables such as curly spinifex and ribbon grass may be almost entirely absent. Dense stands of *Acacia* spp. and *Erythrophleum chlorostachys* may also be induced by too frequent burning. Pindan pastures in this situation are in poor or very poor condition.

No erosion is found on Curly Spinifex-Ribbon Grass pastures in good condition.

- **Fair**

In fair condition the *Triodia bitextura* stand is patchy and *Chrysopogon fallax* may be well grazed and infrequent. The vigour of these desirables is moderate; some crowns may be dead and mature plants may have weak tiller production. Seedlings and young plants of *Chrysopogon fallax* are rarely seen. Seedlings and young plants of *Triodia bitextura* are still present.

The intermediate value perennials *Eragrostis eriopoda, Eriachne obtusa* and the annual *Sorghum stipoideum* frequently make up about one-third of the stand. Undesirables such as *Aristida inaequiglumis, A. hygrometrica* also occupy about one-third of the stand. Short lived annual grasses and forbs, including a range of undesirable forbs such as *Velleia panduriformis, Crotalaria crispata, Senna notabilis* and *Solanum* spp. are sparsely present.

Erosion is very rare, being in the form of small isolated wind scalds, generally near the margins of adjacent degraded frontage country.

- **Poor to very poor**

Desirables are rare and present mainly as well grazed or burnt butts. The stand may still be quite dense but is dominated by *Sorghum stipoideum*, *Aristida inaequiglumis, A. holathera* and *A. hygrometrica,* with occasional tussocks of *Eragrostis eriopoda* and *Eriachne obtusa.* The main forage plants are annual grasses such as *Enneapogon polyphyllus, Panicum cymbiforme* and *P. australiense* and forbs. However, these are short-lived, generally sparse and low in bulk and are quickly grazed out. There are numerous species of undesirable forbs and some of these, such as *Crotalaria crispata* may form moderately dense stands.

As there is still a fair vegetative cover erosion is rare. Small isolated bare sandy patches may occur late in the year but these are quickly covered by *Aristida hygrometrica* during the wet season.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Eragrostis desertorum*	*Aristida inaequiglumis*
Chrysopogon fallax	*Eragrostis eriopoda*	
Sorghum plumosum	*Eriachne obtusa*	
Triodia bitextura		
Triodia pungens		
Triodia schinzii		
Annual grasses		
	Sorghum stipoideum	*Aristida hygrometrica*
		Eriachne ciliata
Miscellaneous species		
	Corchorus sidoides	*Acacia translucens*
	Eremophila longifolia	*Crotalaria crispata*
	Malvaceae herbs/shrubs	*Solanum orbiculatum*
	Tephrosia rosea	

Trees and shrubs

Acacia eriopoda
Acacia hemiglauca
Acacia colei
Acacia lysiphloia
Bauhinia cunninghamii
Buchanania obovata
Carissa lanceolata
Corymbia dichromophloia
Corymbia setosa
Dolichandrone heterophylla
Erythrophleum chlorostachys
Eucalyptus grandifolia
Eucalyptus perfoliata
Grevillea erythroclada
Grevillea pyramidalis
Grevillea sp. aff. *angulata*
Gyrocarpus americanus
Melaleuca acacioides
Flueggea virosa
Ventilago viminalis

Photo 3. Oat-eared Spinifex/Ribbon Grass (OERG) pasture type in good condition, alluvial plain of Parda land system, Shamrock station. Oat-eared spinifex (*Triodia schinzii*) and ribbon grass (*Chrysopogon fallax*) with Broome pindan wattle (*Acacia eriopoda*) dominating the shrub layer.

Photo 4. Oat-eared Spinifex/Ribbon Grass (OERG) pasture type in poor condition. Few heavily grazed oat-eared spinifex (*Triodia schinzii*) butts remaining and little if any ribbon grass (*Chrysopogon fallax*). Soil is not subject to erosion due to the presence of stabilising pindan shrubs and porous soils.

Samphire/Salt Water Couch pasture type (SASW)* 324 km²

Distribution and soil types

The Samphire/Salt Water Couch pasture type occurs on the Anna, Roebuck and Mannerie land systems of the coastal plain as well as on the floors of the coastal gullies in the Gourdon land system. This pasture type occurs beyond the range of tidal influence covering large areas of the Anna land system.

On the Roebuck and Mannerie land systems it occurs as a 100-200 m wide strip along the inland margins plus in limited areas on the coastal plains.

Soil types are solonchak which are saline and light grey silty clays with some areas of fine sandy loams at the southern end of the coastal plain on Thangoo station. Soils of the Anna land system have a thin black topsoil overlying grey subsoils.

Composition

Sporobolus virginicus (salt water couch) dominates this pasture type with succulent samphire shrubs (*Halosarcia indica* and *H. halocnemoides)* present in poorer stands. The salt water couch forms a dense mat often to the exclusion of all other species. *Xerochloa laniflora* (annual rice grass) and *Cynodon dactylon* (couch) are present in some areas. *Salsola tragus* (roly poly), *Flaveria australasica* (yellow daisy), *Corchorus sidoides* (flannel weed) and Malvaceae family shrubs occur rarely. *Cenchrus ciliaris* (buffel grass), *C. setigerus* (Birdwood grass), *Dichanthium fecundum* (bundle-bundle) and *Eragrostis* spp. (lovegrass) are present in minor amounts on the Anna land system.

Along the margins of this pasture type *Melaleuca acacioides* (coastal paperbark) or *Acacia ampliceps* (black wattle) can be present.

Pastoral value

This pasture type has a high pastoral value with salt water couch being readily grazed at all growth stages (Photo 5). This pasture is used as stock fattening areas and is grazed in preference to neighbouring halophytic (salt tolerant) and pindan pasture types.

Condition statements

- **Very good**

Thick stands of *Sporobolus virginicus* (salt water couch) or *Cynodon dactylon* (couch) with some *Panicum decompositum* (native millet) and *P. cymbiforme* (native panic).

- **Good**

Mostly *Sporobolus virginicus* with minor amounts of *Halosarcia* spp. (samphire).

- **Fair**

50:50 *Sporobolus virginicus/Halosarcia* spp. and/or some bare areas. With increased grazing pressure desirable species such as native millet and native panic are eaten out and replaced by samphire. Salt water couch appears to be relatively resistant to overgrazing and recovery is rapid.

- **Poor**

Largely *Halosarcia* spp. with only minor amounts of *Sporobolus virginicus* often with significant areas of bare ground which are subject to wind erosion. Areas of bare ground result from disappearance of samphire caused by stock trampling. Succulents such as samphire are killed by excessive trampling rather than by grazing. Cattle traverse areas of samphire to reach the isolated pockets of salt water couch.

- **Very poor**

Large areas of bare ground with only isolated clumps of *Sporobolus virginicus* and *Halosarcia* spp. with some areas subject to wind erosion.

* Equivalent to Marine Couch Pastures (MACP) of Pasture Types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Chloris* spp.	
Cenchrus setigerus	*Eragrostis setifolia*	
Cynodon dactylon	*Eragrostis tenellula*	
Dichanthium fecundum	*Eriachne obtusa*	
Panicum decomposition		
Sporobolus virginicus		
Xerochloa barbata		
Annual grasses		
Dactyloctenium radulans	*Enneapogon polyphyllus*	
Panicum cymbiforme	*Sorghum stipoideum*	
	Xerochloa laniflora	
Miscellaneous species		
Aerva javanica	*Atriplex* spp.	*Cleome viscosa*
	Corchorus sidoides	*Malvastrum americanum*
	Cyperaceae sedges	*Melhania* sp.
	Flaveria australasica	*Solanum esuriale*
	Halosarcia halocnemoides ssp. *tenuis*	
	Halosarcia indica ssp. *julacea*	
	Neobassia astrocarpa	
	Rhynchosia australis	
	Salsola tragus	

Trees and shrubs

Acacia ampliceps
Melaleuca acacioides
Sesbania formosa

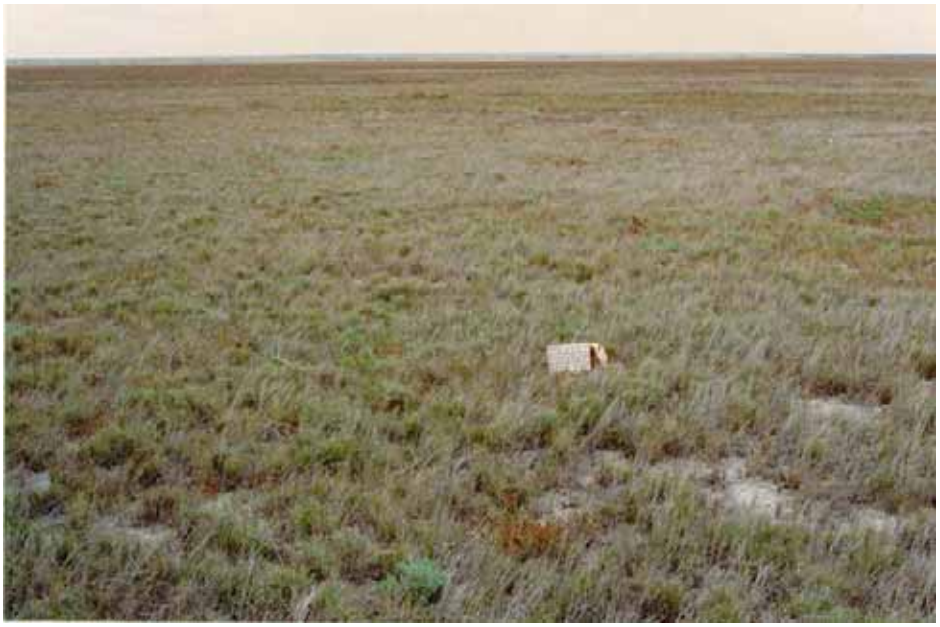


Photo 5. Samphire/Salt Water Couch (SASW) pasture type in very good condition, samphire flats unit of the Roebuck land system, Thangoo station. Salt water couch (*Sporobolus virginicus*) dominates a 100-200 m wide strip on the inland margin of flats with samphire (*Halosarcia auriculata*).

Cenchrus pasture type (CENC)* 217 km²

Distribution and soil types

The Cenchrus pasture type occurs on the coastal margins of the sandplains of the Nita, Mannerie and Yeeda land systems. It also occurs in very localised areas around bores on the sandplain where fertility has been increased with cattle dung and urine. Other occurrences are on the coastal plain of the Anna land system and the very low dunes of the Roebuck land system (Unit 9) and some dunes of the Eighty Mile land system.

The predominant soil type is red earthy sands on the sandplain, solonchak on the coastal plain and calcareous sands on the low dunes.

Composition

The introduced grasses *Cenchrus ciliaris* (buffel grass) and *C. setigerus* (Birdwood grass) are the dominant perennials. One of these species normally prevails and only rarely do they occur together. Normally these grasses dominate the stand to the exclusion of other grasses. The transitional zone between these pastures and spinifex pastures supports some *Triodia pungens* (soft spinifex) whilst the transition to wetter pasture types, such as Littoral, supports *Sporobolus virginicus* (salt water couch).

Aristida holathera (erect kerosene grass), *A. inaequiglumis* (feathertop threeawn), *Eragrostis* spp. (lovegrass) and *Eriachne obtusa* (wire grass) occur in more open pasture stands.

The shrub *Aerva javanica* (kapok bush) commonly occurs with *Acacia translucens* (poverty bush) and Malvaceae family shrubs present in poorer pastures.

Bauhinia cunninghamii (bauhinia) is the dominant tree on the Yeeda land system with *Melaleuca acacioides* (coastal paperbark) dominant on sandplains fringing the coastal plains. *Acacia ampliceps* (black wattle) is the dominant shrub on the low dunes of the Roebuck land system. Other trees including *Acacia colei* (candelbra wattle), *Acacia eriopoda* (Broome wattle) and *Corymbia* spp. (bloodwoods) also occur.

Pastoral value

This pasture type has a high pastoral value and is accessible throughout the year. Stock tends to favour this country in preference to adjacent spinifex pastures. It responds quickly to storms and maintains greenness and palatability longer into the dry than most of the native grasses. This pasture type can tolerate heavy grazing pressure. However, it has been found to be grazed out under prolonged extreme grazing pressure to leave a bare ground surface with no grass cover.

Condition statements

- **Very good**

Pasture contains a thick pure stand of *Cenchrus ciliaris* or *C. setigerus*.

- **Good**

Predominantly *Cenchrus* spp. but with some *Aerva javanica*, *Chrysopogon fallax*, Malvaceae family shrubs and/or *Sporobolus virginicus*.

- **Fair**

Scattered or patchy stands of *Cenchrus* spp. with up to 50 per cent bare ground, often with some *Eriachne obtusa*, *Eragrostis* spp., Malvaceae family shrubs and *Acacia translucens*.

- **Poor**

Occasional or very scattered *Cenchrus* spp. with predominance of undesirable species and much bare ground.

- **Very poor**

Mainly bare ground beneath tree and shrub canopy.

* Equivalent to Buffel Grass Pastures (BUGP) of Pasture Types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Eriachne obtusa*	*Aristida holathera*
Cenchrus setigerus		*Aristida inaequiglumis*
Chrysopogon fallax		
Dichanthium fecundum		
Spinifex longifolius		
Sporobolus virginicus		
Triodia pungens		
Annual grasses		
	Enneapogon sp.	*Aristida hygrometrica*
	Panicum cymbiforme	
	Xerochloa laniflora	
Miscellaneous species		
Aerva javanica	*Corchorus sidoides*	*Acacia translucens*
	Salsola tragus	*Arabidella* sp.
		Crotalaria cunninghamii
		Malvastrum americanum
		Melhania sp.
		Solanum sp.
		Streptoglossa odora
		Waltheria indica

Trees and shrubs

Acacia ampliceps
Acacia bivenosa
Acacia eriopoda
Acacia colei
Bauhinia cunninghamii
Carissa lanceolata
Corymbia dichromophloia
Eucalyptus grandifolia
Grevillea erythroclada
Grevillea pyramidalis
Melaleuca acacioides
Flueggea virosa

Samphire Pasture type (SAMP)* 129 km²

Distribution and soil types

The Samphire pasture type occurs mainly on the Roebuck land system with smaller areas on the Mannerie land system and minor amounts on the Anna, Carpentaria and Great Sandy land systems. This pasture type occurs entirely on the coastal plain with most areas being above the influence of tides. However, some areas are traversed by very shallow tidal channels.

The predominant soil type is solonchak of light grey silty clays. These are saline soils which have a powdery surface when dry but become very sticky when wet.

Composition

The two succulent shrub samphire species *Halosarcia indica* and *H. auriculata* dominate this pasture on the saline coastal plains. The more upright or taller growing *H. auriculata* is dominant in areas under infrequent tidal inundation whilst the lower growing *H. indica* is dominant, and forms denser stands, away from areas affected by tides. *Neobassia astrocarpa* commonly occurs. *Xerochloa laniflora* (annual rice grass) and *X. barbata* (perennial rice grass) are present in areas under low grazing pressure. *Sporobolus virginicus* (salt water couch) is only a minor component of this pasture type, occurring in small isolated shallow depressions. *Flaveria australasica* (yellow daisy) and *Corchorus sidoides* (flannel weed) or *Acacia ampliceps* (black wattle) can occur.

Pastoral value

This pasture has a very low pastoral value with access restricted over the wet season due to boggy soils. It is considered that stock make little use of the succulent samphires and the grazing value lies in the rice grasses which grow during the wet season and the small isolated areas of salt water couch (Photo 6).

Condition statements

- **Very good**

Thick stands of *Halosarcia* spp. (samphires) up to 60 cm tall with minor amounts of *Xerochloa* spp.

- **Good**

Moderately thick stands of *Halosarcia* spp.

- **Fair**

Thinning cover of *Halosarcia* spp. with some areas of bare ground. Stock make little use of samphire pastures and so loss of samphire ground cover is often caused by natural variation in soil salinity and tidal inundation.

- **Poor**

Large areas of bare ground with only scattered *Halosarcia* spp. Susceptible to wind erosion when dry. Large areas of bare ground can result from the death of samphire caused by stock trampling which regularly cross selected areas to gain access to isolated patches of salt water couch.

- **Very poor**

Large bare scalds and mudflats. Susceptible to wind erosion when dry.

* Equivalent to Samphire (SMPP) of Pasture Types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Panicum decomposition	*Eragrostis tenellula*	
Sporobolus virginicus		
Xerochloa barbata		
Annual grasses		
Xerochloa laniflora		
Miscellaneous species		
	Corchorus sidoides	
	Flaveria australasica	
	Halosarcia auriculata	
	Halosarcia halocnemoides ssp. *tenuis*	
	Halosarcia indica ssp. *julacea*	
	Melhania spp.	
	Neobassia astrocarpa	
	Salsola tragus	

Trees and shrubs

Acacia ampliceps
Melaleuca acacioides

Photo 6. Samphire (SAMP) pasture type in fair condition, tidal samphire flats of Carpentaria land system, Frazier Downs. Considerable areas of bare soil with scattered samphire (*Halosarcia auriculata*) and minor wind erosion.

Lobed Spinifex pasture type (LOSP)* 112 km²

Distribution and soil types

The Lobed Spinifex pasture occurs on the oldest landscape elements in the survey area collectively known as the Kimberley Surface. This comprises the Bulka, Parda and Phire land systems which run in a line from Mt Phire in the south, north-eastward through Nita Downs and Shamrock stations.

This pasture type is restricted to those soils with stones mantling the surface. These include lithosols which are stony throughout the profile and lithic phases of red clays and alluvial soils. These lithic phases have a stony surface strew with fine textured profiles beneath.

Composition

Triodia intermedia (lobed or winged spinifex) dominates this pasture type. The community consists of hummocks usually less than 0.7 m wide and up to 1.0 m high (including flowering culms) and it has almost bare inter-hummock areas. The perennial *Aristida latifolia* (feathertop wiregrass) and *Chrysopogon fallax* (ribbon grass) are rare. Forbs are present only in good seasons.

The tree and shrub layer is poorly developed and sparse. The most common species are *Eucalyptus brevifolia* (snappy gum), *Acacia victoriae* (bramble wattle) and *Gossypium australe* (wild cotton).

Pastoral value

The pastoral value of these pastures is very low. Lobed spinifex is unattractive to stock in nearly all stages of growth and forms an extremely poor pasture (Photo 7). Top feed is virtually absent.

Small inclusions of other pasture types such as Ribbon Grass and Oat-eared Spinifex/Ribbon Grass may marginally improve the pastoral value but, because of preferential use, these are readily degraded.

At best Lobed Spinifex pastures should be regarded as providing a subsistence diet at very low stocking capacity.

Condition statements

Those presented by Payne, Kubicki and Wilcox (1974) as summarised below were used in this survey.

- **Good to very good**

In good condition the ground cover afforded by lobed spinifex tussocks is optimal for the particular site. Inherently poor sites such as stony lower slopes with high run-off potential will never be fully covered by spinifex. More favoured run-on sites will support denser vegetation, but there is still likely to be 1-3 m between tussocks. There are occasional vigorous plants of other desirable perennial grasses such as *Triodia bitextura, T. pungens* and *Chrysopogon fallax.* Depending on seasonal conditions there is a sparse to negligible inter-tussock ground cover of annual grasses and forbs.

In good condition there is no induced erosion on this pasture land. There are frequent patches of bare, sealed ground, but these are relatively stable. On steep lower slopes receiving run-off from adjacent lands, there may be shallow rills and gutters, but the shallow depth to parent rock prevents these from incising deeply. On other sites such as stripped surfaces and rocky breakaways and plateaux, the high proportion of rock outcrop, boulder mantle and lateritised strew protects the soil surface from erosion.

- **Fair**

In this condition the ground cover afforded by lobed spinifex may still be optimal for the site and is undisturbed. However, the few associated desirable perennial grasses will be only moderately productive and have some weak and moribund crowns. A very sparse cover of annual grasses and forbs may be present. Some of these are palatable intermediate value species, but there is an increasing proportion of useless and undesirable species such as *Aristida hygrometrica, Trichodesma zeylanicum, Senna notabilis* and *Solanum* sp.

* Equivalent to Hard Spinifex Plain Pastures (HSPP) of Pasture Rypes of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

Because of the rocky stone cover and shallow soils of most sites there is no erosion on the bulk of the Lobed Spinifex pastures in fair condition.

- **Poor to very poor**

Lobed spinifex, being unpalatable, still occurs over the site but there are virtually no desirable perennial grasses in the inter-hummock spaces. A very sparse cover of annual grasses and forbs may be present in season. There may be minor erosion in the form of thin surface sheeting and shallow rills and gutters on surfaces that are not protected by gravelly or stony mantles.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Chrysopogon fallax	*Eriachne obtusa*	
Dichanthium fecundum		
Triodia intermedia		
Triodia pungens		
Miscellaneous species		
	Eremophila bignoniiflora	*Acacia translucens*
		Gossypium australe

Trees and shrubs

Acacia eriopoda
Acacia lysiphloia
Acacia victoriae
Carissa lanceolata
Eucalyptus brevifolia
Grevillea pyramidalis

Photo 7. Lobed Spinifex (LOSP) pasture type in very good condition on a ring plain of the Parda land system, Shamrock station. Lobed spinifex (*Triodia intermedia*) is unattractive to stock and has a very low carrying capacity. Note conical hill (unit 1) of the Parda land system in the distance.

Coastal Dune pasture type (CSDN) 53 km²

Distribution and soil types

The Coastal Dune pasture type occurs on the dunes of the Eighty Mile land system on the western edge of the survey area.

Soils are deep, loose siliceous or calcareous sands.

Composition

Spinifex longifolius (coastal spinifex) is the dominant perennial with *Whiteochloa airoides* (dune tussock grass) commonly present.

Triodia pungens (soft spinifex) and *Cenchrus ciliaris* (buffel grass) can also occur. *Aerva javanica* (kapok bush), *Salsola tragus* (roly poly) and *Crotalaria cunninghamii* (parrot pea) are sometimes present with *Malvastrum americanum* (spiked mallow) being rare.

Acacia bivenosa (dune wattle) is the dominant tall shrub but most of this pasture land is open with no shrub canopy.

Pastoral value

The pastoral value of these pastures is very low with use restricted by lack of available stock water. The pastures are generally unattractive to stock. The dunes are susceptible to wind erosion when the protective plant cover is removed.

In areas to the south of the survey area (Anna Plains station) *Cenchrus ciliaris* (buffel grass) can predominate and stocking rates will be accordingly higher than those given in this report.

Condition statements

Few traverse recordings were made on this pasture type with only two levels of condition being assessed.

- **Good to very good**

Pasture contains a thick pure stand of *Spinifex longifolius* or *Whiteochloa airoides*, ± *Cenchrus ciliaris*.

- **Fair**

Pasture dominated by *Spinifex longifolius* but with bare sand areas plus undesirables such as *Crotalaria cunninghamii*.

It is envisaged that poor condition pastures would have significant bare sand areas and be dominated by undesirable species.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Whiteochloa airoides*	
Cenchrus setigerus		
Dichanthium fecundum		
Panicum decompositum		
Spinifex longifolius		
Triodia pungens		
Miscellaneous species		
Aerva javanica	*Lycium australe*	*Crotalaria cunninghamii*
Rhynchosia australis	*Salsola tragus*	*Malvastrum americanum*
		Melhania spp.

Trees and shrubs

Acacia ampliceps

Acacia bivenosa

Oat-eared Spinifex pasture type (OESP)* 19 km²

Distribution and soil types

The Oat-eared Spinifex pasture type occurs predominantly on some parts of the sandplains of the Yeeda land system. Only minor areas were recorded on the Parda land system. This type was only recorded on Shamrock station.

The predominant soil is red earthy sands characteristic of the sandplain.

Composition

Triodia schinzii (oat-eared spinifex) is the predominant species. Associated perennials are scarce and include *Triodia pungens* (soft spinifex), *Eriachne obtusa* (wire grass), *Aristida holathera* and *Aristida inaequiglumis* (feathertop threeawn).

Dominant trees and shrubs include *Acacia eriopoda* (Broome pindan wattle), *A. colei* (candelbra wattle), *Corymbia dichromophloia* (variable-barked bloodwood), *Bauhinia cunninghamii* (bauhinia) and *Grevillea pyramidalis* (caustic bush).

Pastoral value

Oat-eared Spinifex pastures have a moderate grazing value but carrying capacity is low. They are readily accessible throughout the year and are capable of being utilised on a year-long basis. They are generally grazed by stock at all stages of growth but young fresh growth is favoured. They persist well during droughts and are a useful drought reserve. Cattle appear to favour grazing oat-eared spinifex over *Triodia pungens* (soft spinifex) and so Oat-eared Spinifex pastures are rated as having a slightly higher carrying capacity than Soft Spinifex pastures.

Condition statements

This pasture type corresponds to the Curly Spinifex pasture land described by Payne, Kubicki and Wilcox (1974) with *Triodia schinzii* replacing *Triodia bitextura* as the predominant perennial. Apart from this change, the condition guides for Curly Spinifex pasture land were used and are summarised below.

- **Good to very good**

In this condition the desirable oat-eared spinifex forms by far the greatest bulk of the stand. Other desirable perennials are sparsely present and annual grasses and forbs form a sparse ground cover between the spinifex tussocks. Towards the end of the year the inter-tussock spaces may become bare as the annuals are removed by preferential grazing. Undesirable species such as *Aristida inaequiglumis, A. hygrometrica, Waltheria indica* and *Heliotropium* sp. may be present, but are very scattered and offer a negligible contribution to the overall stand.

Density of the oat-eared spinifex varies considerably from site to site (0.3-2 m or more between tussocks), but for any particular site the spinifex tussocks are usually uniformly distributed.

In good condition the size of individual spinifex plants can be variable. In old stands the plants become large, straggly and dominant almost to the exclusion of other species. In young stands such as after a recent fire, there are large numbers of small spinifex seedlings with a good range of intermediate value annual grasses and forbs between. After a fire there may be a short-term increase in the abundance of undesirable species such as *Aristida hygrometrica* but, provided stocking is not excessive and burning not too frequent, there is rapid return to spinifex dominance.

There is no erosion on Oat-eared Spinifex pasture lands in good to very good condition.

* Equivalent to Soft Spinifex Pastures (SSPP) of pasture types of the Kimberley – definitive list as at 31 March 2004 (unpublished, WADA Kununurra).

- **Fair**

In fair condition oat-eared spinifex is still the dominant species present, but an increasing proportion of the stand is made up of undesirable grasses such as *Aristida inaequiglumis* and *A. hygrometrica.* Weedy undesirables such as *Waltheria indica, Heliotropium* sp., *Cleome viscose* and *Euphorbia* sp. are fairly common. The density of spinifex is below site potential and occurrence may be clumpy or less uniform than for good condition.

There is no erosion on the sandy, loamy or rocky soils associated with land systems supporting fair condition Oat-eared Spinifex pastures. There may be patchy, almost bare sandy surfaces, but these are not susceptible to wind or water erosion.

- **Poor to very poor**

In this condition oat-eared spinifex is only sparsely present and other desirables are virtually absent. There may be 10-30 m between tussocks. On sandy surfaces the trend is to dominance by undesirable annual grasses, there may be dense stands of the useless *Aristida hygrometrica.* Because of the preponderance of unpalatable species, or bare ground, Oat-eared Spinifex pastures in poor condition are of little use for grazing.

There is virtually no erosion associated with Oat-eared Spinifex pastures in poor to very poor condition on most land systems.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Sorghum plumosum	*Eragrostis eriopoda*	*Aristida inaequiglumis*
Triodia bitextura	*Eriachne obtusa*	*Aristida holathera*
Triodia pungens		
Triodia schinzii		
Annual grasses		
	Sorghum stipoideum	*Aristida hygrometrica*

Trees and shrubs

Acacia eriopoda
Acacia colei
Bauhinia cunninghamii
Corymbia dichromophloia
Corymbia setosa
Erythrophleum chlorostachys
Grevillea pyramidalis

Littoral pasture type (LITT)* 14 km²

Distribution and soil types

The Littoral pasture type occurs predominantly on the Roebuck and Carpentaria land systems. It is confined to the inland margin of the coastal plain which borders the neighbouring sandplain.

The Littoral pasture land described by Payne, Kubicki and Wilcox (1974) includes bare saline mud flats, samphire flats, outer flats with mangrove communities and small dunes. These components have been separately identified in this survey to become Samphire (SAMP), Samphire/Salt Water Couch (SASW) and Cenchrus (CENC) pastures as described in this section leaving the Littoral pasture type which is described as being confined to the inland margin of the coastal plain.

The soils are predominantly solonchak being black silt overlying hard coral. Topsoils are very powdery when dry and sticky when wet.

Composition

The botanical composition of the Littoral pasture type is variable, depending on soil salinity and soil type. In areas above tidal influence and adjacent to pindan the stand is dominated by *Sporobolus virginicus* (salt water couch) with some *Cynodon dactylon* (couch), *Xerochloa barbata* (perennial rice grass) and *X. laniflora* (annual rice grass). On wetter and more salty areas *Neobassia astrocarpa* and *Scaevola spinescens* (currant bush) become dominant. The transitional zone between these Littoral pastures and land systems with pindan pastures commonly supports *Eriachne obtusa* (wire grass), *Cenchrus ciliaris* (buffel grass) and *C. setigerus* (Birdwood grass).

Melaleuca acacioides (coastal paperbark) is the characteristic tree species with occasional *Acacia* spp. and *Bauhinia cunninghamii* (bauhinia) on drier areas.

Pastoral value

This pasture type has a moderate pastoral value but access to stock can be restricted over the wet season due to boggy soils. The salt water couch, couch and rice grasses are palatable and very attractive to stock. Stock tends to favour and concentrate on this country in preference to adjacent pindan pastures. Consequently overuse of these pastures is prevalent resulting in the elimination of desirable species and significant areas of bare ground (Photo 8).

Control of stock in this pasture type is essential to prevent degradation. Degraded areas require spelling for a number of consecutive wet seasons to allow for recovery.

Condition statements

Those presented by Payne, Kubicki and Wilcox (1974) as summarised below were used in this survey.

- **Good to very good**

Littoral pastures in good to very good condition are predominantly rice grass grassland. The dominant perennials are *Xerochloa barbata*, *Leptochloa fusca, Eragrostis falcata* and *Sporobolus virginicus.* Scattered throughout the pasture are tussocks, or patches of *Eriachne obtusa, Leptochloa brownii, Aristida holathera* and *Chrysopogon fallax,* but these collectively, constitute only about a quarter to a third of the stand. Some forbs and herbs are usually present but these contribute little to the overall stand.

In this condition the grassland is quite dense. Rice grass tussocks are about 0.2-0.5 m high. There is virtually no bare ground between the tussocks.

In good to very good condition there is virtually no erosion on this pasture land. There may be isolated patches (5-10 m in diameter) slightly below the level of, and probably more saline than, the surrounding

* Equivalent to Littoral Pastures (LITP) of Pasture Types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

sandy surfaces. They may be almost bare or support less vigorous and dense stands of vegetation than the surrounding country.

- **Fair**

In fair condition the density and vigour of perennial rice grass is somewhat below potential for the particular site. In most cases this condition would be indicated when the spacing between tussocks is 1-1.5 m and height less than 0.3 m. Ground cover between perennial tussocks is patchy and consists mainly of *Sporobolus australasicus* and *Xerochloa laniflora.*

The pasture is still dominated by *Xerochloa barbata*. Other desirable perennials such as *Eragrostis falcata*, *Leptochloa fusca*, *Chrysopogon fallax* and *Sporobolus virginicus* are sparsely present. Intermediates and undesirable such as *Eriachne obtusa*, *E. glauca* and *Aristida holathera* may, collectively, increase their proportion in the stand to a third or more.

Minor erosion is common on Littoral pasture lands in fair condition. This is in the form of patchy bare areas 10-20 m in diameter. Wind, rather than water, is the major agent responsible and there may be hummocking and wind piling of soil around obstacles, or at the margins of bared areas. There may be occasional small rills.

- **Poor to very poor**

In this condition this pasture land has a patchy stand of desirable perennials and may be dominated by annuals and undesirable species. Perennials such as *Xerochloa barbata, Eragrostis falcata* and *Sporobolus virginicus* are sparse and show poor vigour. The stand may be dominated by *Eriachne obtusa, Xerochloa laniflora, Eriachne glauca* and *Aristida holathera.* By mid or late dry season there are often considerable areas of sandy surfaces supporting only scattered annual remnants. Heavy overuse by stock, resulting in almost complete removal of palatable annual and perennial components, is responsible for this situation. Such sites are susceptible to wind erosion.

Minor and moderate erosion is common on Littoral pasture lands in poor or very poor condition. There are often large patches of irregularly shaped bared area with wind piling and hummocking at the margins. Shallow rills and gutters are frequently present. However, the flat topography and tough structure of the heavy clay soils underlying at shallow depth prevents gutters from incising deeper than about 0.3 m.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Cenchrus ciliaris	*Eriachne obtusa*	*Aristida holathera*
Cynodon dactylon		*Eriachne glauca*
Leptochloa fusca		
Eragrostis spp.		
Sporobolus virginicus		
Xerochloa barbata		
Annual grasses		
	Xerochloa laniflora	
Miscellaneous species		
	Corchorus sidoides	*Scerolaena* spp.
	Cyperaceae family	
	Halosarcia halocnemoides ssp. *tenuis*	
	Halosarcia indica ssp. *julacea*	
	Neobassia astrocarpa	
	Scaevola spinescens	

Trees and shrubs

Acacia ampliceps
Acacia eriopoda
Acacia colei
Bauhinia cunninghamii
Melaleuca acacioides

Photo 8. Littoral (LITT) pasture type in poor condition, inner slope unit of Roebuck land system, Thangoo station. Considerable areas of bare soil with only a few annual species and a thick cover of coastal paperbarks (*Melaleuca acacioides*).

Ribbon Grass pasture type (RGRB)* 13 km²

Distribution and soil types

The Ribbon Grass pasture type occurs occasionally on some sandplains of the Yeeda land system and the alluvial plain unit of the Parda land system. It is the least prevalent pasture type in the survey area being recorded only in southern parts of Shamrock station. Other small areas were noted just outside the survey area on the southern boundary of Roebuck Plains station.

The predominant soil is red earthy sands of the sandplain plus alluvial soils on the Parda land system.

Composition

This pasture type is usually confined to areas receiving below 500 mm annual rainfall. *Chrysopogon fallax* (ribbon grass) is the dominant perennial and on some sites may dominate to the virtual exclusion of other grasses. It can be found in association with *Triodia pungens* (soft spinifex) and *Triodia schinzii* (oat-eared spinifex). *Cymbopogon procerus* (lemon grass) was found as a minor component.

The most common trees and shrubs are *Acacia eriopoda* (Broome pindan wattle), *A. translucens* (poverty bush) and *A. lysiphloia* (turpentine wattle). Other trees and shrubs commonly associated with ribbon grass pasture lands are *Corymbia dichromophloia* (variable barked bloodwood), *Bauhinia cunninghamii* (bauhinia), *Atalaya hemiglauca* (whitewood) and *Dolichandrone heterophylla* (lemonwood).

Pastoral value

This pasture land is of moderate-high value. It is readily accessible throughout the year.

These pastures can be grazed on a year-long basis but periodic wet season spelling may need to be incorporated to ensure the maintenance and vigour of desirable perennials.

Condition statements

Those presented by Payne, Kubicki and Wilcox (1974) as summarised below were used in this survey.

- **Good to very good**

In this condition, desirable perennials such as *Chrysopogon fallax, Triodia pungens* and *T. bitextura* make up the bulk of the stand. The spinifex grasses, singly or together, may make up one-third of the total stand and *Chrysopogon fallax* is always prominent. Tussocks of the desirables are about 2-5 m apart and show good vigour and production. Seedlings and young plants of the desirables are present. There are minor amounts of *Sorghum plumosum, Sehima nervosum, Eriachne obtusa* and *Aristida inaequiglumis.* Annuals and forbs form a thin ground cover in the inter-tussock areas but contribute little to the overall stand.

In good to very good condition there is no erosion on this pasture type.

- **Fair**

In fair condition *Chrysopogon fallax* shows moderate vigour but may make up only one-third or less of the bulk of the stand. Tussocks are 10-15 m apart, or perhaps closer, but clumpy in distribution over the site. Some tussocks are weak and show heavy utilisation.

Triodia pungens and/or *T. bitextura* show signs of increasing utilisation but are still moderately productive and vigorous. They occupy one-third or more of the stand and hummocks are about 5-10 m apart.

* Equivalent to Ribbon Grass Pastures (RGRP) of Pasture Types of the Kimberley – definitive list as at 31 March 2004 (Unpublished, WADA Kununurra).

The intermediate *Eriachne obtusa* and the undesirables such as *Aristida inaequiglumis* collectively constitute up to one-third of the stand. Inter-tussock cover afforded by annual grasses and forbs is sparse. Seedlings and young plants of desirable species are only occasionally seen.

- **Poor to very poor**

In this condition *Chrysopogon fallax* is sparse to virtually absent and occupies only a minor proportion of the stand. Tussocks are 20-30 m or more apart and vigour and production are poor. The spinifex hummocks frequently show evidence of heavy utilisation with poor-moderate vigour and are 15 m or more apart. Seedlings of desirable species are absent.

Scattered plants of the intermediate perennial *Eriachne obtusa* are present and there may be scattered remnants of annuals such as *Xerochloa laniflora, Sporobolus australasicus,* and *Enneapogon polyphyllus.* There is an increasing range of undesirable species such as *Aristida hygrometrica, Heliotropium* sp., *Solanum* sp., *Trichodesma zeylanicum* and *Streptoglossa odora;* although nowhere do they form dense stands. Total ground cover afforded by vegetation is poor.

In poor to very poor condition moderate erosion is common but this was not seen in the Broome survey area.

Pasture species

DESIRABLE	INTERMEDIATE	UNDESIRABLE
Perennial grasses		
Chrysopogon fallax	*Cymbopogon procerus*	*Aristida inaequiglumis*
Dichanthium fecundum	*Eriachne obtusa*	
Triodia pungens		
Triodia schinzii		
Annual grasses		
	Enneapogon polyphyllus	*Aristida hygrometrica*
	Sporobolus australasicus	
	Xerochloa laniflora	
Miscellaneous species		
	Eremophila longifolia	*Acacia translucens*
		Heliotropium sp.
		Solanum sp.
		Streptoglossa odora

Trees and shrubs

Acacia eriopoda
Acacia lysiphloia
Atalaya hemiglauca
Bauhinia cunninghamii
Corymbia dichromophloia
Dolichandrone heterophylla
Eucalyptus tectifica

Range condition

In concept, range condition is a measure of the degree to which the vegetation and soil resources of a particular site, land unit or land system deviate from the optimal condition which could be expected at that site, land unit or land system under a specific type of land use – in this case pastoral use. This differs somewhat from the traditional concept (Dyksterhius 1949) of deviation from climax vegetation in that it recognises that climax vegetation cannot be defined in many cases and that it is not always the most productive for pastoral purposes (Payne, Curry and Spencer 1987).

Three broad classes of range condition were derived (see section on survey methods) from assessments of soil erosion and pasture condition made during traverses of the survey area. These levels of range condition are referred to as good, fair and poor.

Country is in good range condition when grazing resources are either near optimal or not seriously diminished from the ideal for the particular country type.

Country in fair range condition is in reasonable order, but careful management is required to ensure that condition and productivity does not deteriorate further. Changes in management practices may be necessary to maintain or improve condition.

Country in poor range condition will not sustain grazing at anywhere near its potential level and changes in management to initiate improvement are required. Country in this condition is degraded with perennial pastures producing at well below potential. Active soil erosion may or may not be present. In extreme cases, complete protection from grazing and other special remedial treatments are required to effect recovery.

A condition statement for the whole survey area was compiled (see Table 13) by examining the entire traverse data recorded during the survey. The table presents an overall summary, obtained by traversing along many station access tracks and fence lines. It was not possible to traverse some areas due to the absence of tracks but many of these were accessed on foot and invariably found to be in good range condition. Erosion was not a serious problem over any part of the survey area with only 2.0 per cent of traverse observations recording minor erosion and 0.2 per cent recording moderate erosion. This erosion was limited to four land systems; Great Sandy (2% of traverse records with minor erosion, 1% moderate), Nita (1% minor erosion), Phire (29% minor erosion) and Roebuck (2% minor erosion) A small area of moderate water erosion was also observed on the conical hills unit of the Parda land system but this area was not traversed.

Eighty-four per cent of traverse observations indicated pasture condition in the fair to very good range. However, some pasture types are seriously degraded with 16 per cent of traverse observations indicating poor to very poor pasture condition.

Table 13. Traverse summary, total over all land systems (1,128 traverse recordings were made on 11 land systems)

Wind erosion	%	Water erosion	%	Total erosion	%	Pasture condition	%	Range condition	%
Nil	99.8	Nil	98.0	Nil	97.8	Very good	27	Good	63
Minor	-	Minor	2.0	Minor	2.0	Good	36	Fair	21
Moderate	0.2	Moderate	-	Moderate	0.2	Fair	21	Poor	16
Severe	-	Severe	-	Severe	-	Poor	12		
						Very poor	4		

The range condition assessment of the whole survey area was as follows:

> 63 per cent of traverse observations indicated good range condition, 21 per cent indicated fair range condition and 16 per cent indicated poor range condition.

Overall, land systems in the survey area were stable with little erosion but some pastures were in a degraded state.

Condition statements were also derived for individual land systems and land units (statements for the latter are not presented here). Table 14 groups the land systems of the survey area in decreasing order of pastoral value and indicates the condition of each system.

Land systems in poor range condition occur in three regions of the survey area. Firstly, pastures on the margin between the coastal plain and inland sandplain are very palatable to stock and so tend to be overgrazed unless cattle movements are strictly controlled (Roebuck and Yeeda land systems). Secondly, areas of the Yeeda land system which are close to bores or have been overgrazed through excessive stocking were also in poor range condition. Thirdly, in the Great Sandy Desert and on its western margin, salty clay pans of the Great Sandy land system were in poor range condition but this is a natural phenomenon and all any future management should aim to do is prevent stock access to these areas. Areas of the lateritic plain of the Phire land system are part of a fragile ecosystem which should probably not be stocked again with cattle or if it is, then at extremely low rates in order to preserve pasture cover and prevent erosion.

Stocking rates

Table 15 shows suggested stocking rates for all pasture types, at three condition levels, within the survey area. These are based largely on those given by Payne, Kubicki and Wilcox (1974) for similar pastures in the West Kimberley. Other sources of information were rates given by Payne, Mitchell and Holman (1988) for coastal pastures plus experience gained during the survey on pasture condition under particular stocking rates and under the climate of the survey area.

These stocking rates are a guide to long term productive potential and are not intended to be rigidly applied by managers or used as a basis for legislative controls. The actual grazing value and appropriate stocking of a particular pasture at any time varies enormously with seasonal conditions, perennial pasture condition and the degree of recent use. An inflexible adherence to suggested stocking rates is not to be recommended but the aim is rather to match stocking with the variations in pasture condition as closely as possible.

By using the suggested stocking rates shown in Table 15, together with the traverse data on pasture condition it was possible to calculate the estimated carrying capacity for the observed range condition of each station in the survey area. Potential carrying capacities of each station were also calculated for when all pastures are in good condition and the station is fully developed. These calculations are detailed in the individual station reports (Cotching *et al.* 1990 a,b,c,d). The estimated carrying capacities are purely guideline figures to assist managers with the planning or revising of management programmes.

Since this survey there has been a review, in 2003, of potential carrying capacities of all stations in the Kimberley (Baird and Novelly, unpublished). This has resulted in increases in the potential carrying capacities of four of the five stations covered in this report and a reduction in capacity for the fifth station. The process for determining the re-assessments has been reported by Novelly and Baird (2001) and the Department of Local Government and Regional Development (2004).

Table 14. Condition summary of land systems within the survey area

Pastoral value	Land system	Area (ha)	No. of traverse observations	Percentage of observations in range condition shown (%)		
				Good	Fair	Poor
High						
Less than 12.5 ha/cattle unit	Anna	11,324	50	64	24	12
Moderate						
12.5-25 ha/cattle unit	Mannerie	8,460	21	47	43	10
	Roebuck	33,113	121	49	30	21
Very low						
More than 40 ha/cattle unit	Bulka	2,835	-	100	-	-
	Carpentaria	3,788	2	100	-	-
	Eighty Mile*	7,015	4	75	-	25
	Gourdon	6,533	24	75	8	17
	Great Sandy	191,919	86	91	3	6
	Nita	91,920	131	85	12	3
	Parda	15,280	19	74	21	5
	Phire	47,365	62	66	16	18
	Yeeda	446,820	608	58	23	19
Total		866,372	1,128	63	21	16

* Higher pastoral value where buffel grass widely established.

Table 15. Suggested stocking rates of pastures at three condition levels

Pasture type	Condition level					
	Good		Fair		Poor	
	cu/km	ha/cu	cu/km	ha/cu	cu/km	ha/cu
Cenchrus (CENC)	10.0	10	5.0	20	2.0	50
Coastal Dunes (CSDN)	1.7	60	1.0	100	0.5	200
Littoral (LITT)	4.5	22	2.0	50	1.0	100
Lobed Spinifex (LOSP)	1.0	100	0.8	125	0.4	250
Oat-eared Spinifex/Ribbon Grass (OERG)	2.2	45	1.4	71	0.5	200
Oat-eared Spinifex (OESP)	2.0	50	1.3	77	0.5	200
Ribbon Grass (RGRB)	5.0	20	2.5	40	0.5	200
Samphire (SAMP)	1.0	100	0.7	150	0.4	250
Samphire/Salt Water Couch (SASW)	12.5	8	5.0	20	2.0	50
Soft Spinifex (SOSP)	1.8	55	1.2	83	0.5	200

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APPENDIX 1: LIST OF PLANT SPECIES

Botanical name	Common name
Acacia ampliceps	black wattle
Acacia ancistrocarpa	Fitzroy wattle
Acacia bivenosa	dune wattle
Acacia drepanocarpa	narrow leaf wattle
Acacia eriopoda	Broome pindan wattle
Acacia hilliana	needle leaf wattle bush
Acacia colei	candelbra wattle
Acacia lysiphloia	turpentine wattle
Acacia orthocarpa	needle leaf wattle
Acacia translucens	poverty bush
Acacia victoriae	bramble wattle
Aerva javanica	kapok bush
Arabidella sp.	cress
Aristida contorta	bunched kerosene grass
Aristida holathera	erect kerosene grass
Aristida hygrometrica	corkscrew grass
Aristida inaequiglumis	feathertop threeawn
Atalaya hemiglauca	whitewood
Atriplex sp.	saltbush
Avicennia marina	mangrove
Bauhinia cunninghamii	bauhinia
Brachychiton viscidula	kurrajong
Buchanania obovata	wild mango
Carissa lanceolata	conkerberry
Cenchrus ciliaris	buffel grass
Cenchrus setigerus	Birdwood grass
Chloris sp.	windmill grass
Chrysopogon fallax	ribbon grass
Cleome viscosa	mustard bush
Corchorus sidoides	flannel weed
Corymbia dichromophloia	variable-barked bloodwood
Corymbia ferruginea	rusty bloodwood
Corymbia setosa	rough-leaf bloodwood
Crotalaria crispata	Kimberley horse poison
Crotalaria cunninghamii	parrot pea
Cymbopogon procerus	lemon grass
Cynodon dactylon	couch
Cyperaceae family	sedge
Dactyloctenium radulans	button grass
Dichanthium fecundum	bundle-bundle
Dolichandrone heterophylla	lemonwood
Enneapogon polyphyllus	limestone grass
Enneapogon sp.	

Botanical name	Common name
Eragrostis desertorum	desert lovegrass
Eragrostis eriopoda	woollybutt
Eragrostis setifolia	neverfail grass
Eragrostis tenellula	delicate lovegrass
Eremophila bignoniiflora	gooramurra
Eremophila longifolia	berrigan
Eriachne ciliata	slender wandarrie grass
Eriachne obtusa	wiregrass
Erythrophleum chlorostachys	Cooktown ironwood
Eucalyptus brevifolia	snappy gum
Eucalyptus grandifolia	cabbage gum
Eucalyptus perfoliata	twin-leaf bloodwood
Eucalyptus tectifica	Darwin box
Flaveria australasica	yellow daisy
Gardenia megasperma	wild gardenia
Gossypium australe	wild cotton
Grevillea sp. aff. *angulata*	prickly grevillea
Grevillea agrifolia	blue grevillea
Grevillea erythroclada	needle leaf grevillea
Grevillea pyramidalis	caustic bush
Grevillea refracta	silver leaf grevillea
Grevillea striata	beefwood
Gyrocarpus americanus	stinkwood
Hakea lorea	corkwood
Halosarcia auriculata	upright samphire
Halosarcia halocnemoides ssp. *tenuis*	samphire
Halosarcia indica ssp. *julacea*	samphire
Lycium australe	boxthorn
Malvaceae family	
Malvastrum americanum	spiked mallow
Melaleuca acacioides	coastal paperbark
Melhania sp.	
Neobassia astrocarpa	
Owenia reticulata	desert walnut
Panicum cymbiforme	native panic
Panicum decompositum	native millet
Rhynchosia australis	native rock trefoil
Salsola tragus	roly poly
Scaevola spinescens	currant bush
Scerolaena sp.	bindii
Flueggea virosa	dogwood
Senna notabilis	cockroach bush
Sesbania formosa	swamp corkwood
Solanum esuriale	devils apple
Solanum orbiculatum	tomato bush

Botanical name	Common name
Sorghum plumosum	perennial sorghum
Sorghum stipoideum	annual native sorghum
Spinifex longifolius	coastal spinifex
Sporobolus virginicus	salt water couch
Streptoglossa odora	stinkweed
Stylosanthes sp.	stylo
Tephrosia rosea	Flinders river poison
Trichodesma zeylanicum	camel bush
Triodia bitextura	curly spinifex
Triodia intermedia	lobed spinifex
Triodia pungens	soft spinifex
Triodia schinzii	oat-eared spinifex
Triodia sp.	feathertop spinifex
Ventilago viminalis	supplejack
Waltheria indica	
Whiteochloa airoides	dune tussock grass
Xerochloa barbata	perennial rice grass
Xerochloa laniflora	annual rice grass

APPENDIX 2: REPRESENTATIVE SOIL PROFILE DESCRIPTIONS

Anna – Tidal wet soil summary

Land system inventory point no.	FRA 18
Date	21 March 1990
Station	Frazier Downs
Traverse no.	7
Location on traverse	7 km
Grid reference	1:100,000 Map sheet 3260 La Grange
Australian map grid (AMG) co-ordinates	E 361 100, N 7 917 700, Zone 51
Photo no. and date	La Grange run 12/5109,1988
Land system	Anna
Land unit	2
Australian Soil Classification	Kandosolic Extratidal Hydrosol
WA Soil Group	Tidal wet soil
Great Soil Group	Solonchak
Soil family	Salt flat soil
Principal Profile Form	Uc 6.51
Parent material	Estuarine mud
Geomorphology	Landform – paleo-tidal coastal plain position – slope – flat
Erosion	Nil
Surface condition	Hard setting
Moisture conditions	Dry
Observation method	Pit and auger
Described by	W.E. Cotching

Anna – Tidal wet soil profile

A	0-13 cm	Very dark grey (2.5YR 3/0); silty clay; moderately strong consistence; massive structure; few fine roots; sharp smooth boundary.
B	13-40 cm	Light grey and greyish brown (2.5YR 7/2 and 5/2); silty clay; very strong consistence; massive structure; few very fine roots; indistinct smooth boundary.
C	40-100^{+} cm	Light grey (2.5YR 7/2); silty clay; very strong consistence; massive structure.

Roebuck – Tidal wet soil summary

Land system inventory point no.	THA 5
Date	12 January 1990
Station	Thangoo
Traverse no.	3
Location on traverse	15 km
Grid reference	1:100,000 Map sheet 3361 Villaret
Australian map grid (AMG) co-ordinates	E 428 200, N 7 987 600, Zone 51
Photo no. and date	La Grange run 3/5114, 1988
Land system	Roebuck
Land unit	1
Australian Soil Classification	Haplic Supratidal Hydrosol
WA Soil Group	Tidal wet soil
Great Soil Group	Solonchak
Soil family	Fine textured samphire soils
Principal Profile Form	Uf 1.41
Parent material	Estuarine mud
Geomorphology	Landform - paleo-tidal coastal plain position - slope - flat
Erosion	Nil
Surface condition	Soft
Moisture conditions	Slightly moist to moist at depth
Observation method	Pit and auger
Described by	W.E. Cotching

Roebuck – Tidal wet soil profile

A11	0-4 cm	Light brownish grey (10YR 6/2); silty clay; very weak consistence; massive structure; distinct smooth boundary.
A12	4-10 cm	Light brownish grey (10YR 6/2); silty clay; moderately strong consistence; massive structure; many very fine roots; sharp wavy boundary.
AC	10-25 cm	Light grey and light brownish grey (10YR 7/2 and 6/2); silty clay; very firm consistence; massive structure; indistinct smooth boundary.
C	25-80 cm	Light grey (10YR 7/2); silty clay; very firm consistence; massive structure; few very fine roots; many 5 mm diameter pores; indistinct smooth boundary.
Cg	80-100 cm	Light grey (2.5YR 7/2); silty clay; moderately strong consistence; massive structure; very few fine roots; few medium distinct light brownish grey and light yellowish brown (2.5YR 6/4 and 6/6) mottles.

Great Sandy – Red deep sand summary

Land system inventory point no.	NIT 25
Date	22 February 1990
Station	Nita Downs
Traverse no.	8
Location on traverse	42 km
Grid reference	1:100,000 Map sheet 3359 Phire
Australian map grid (AMG) co-ordinates	E 401 700,N 7 851 200, Zone 51
Photo no. and date	Munro run 6/5532, 1985
Land system	Great Sandy
Land unit	1
Australian Soil Classification	Arenic Rudosol
WA Soil Group	Red deep sand
Great Soil Group	Siliceous sands
Soil family	Cockatoo
Principal Profile Form	Uc 1.23
Parent material	Aeolian Quaternary sand
Geomorphology	Landform - dune position - crest slope - 15°
Erosion	Moderate wind erosion with some blowouts
Surface condition	Loose
Moisture conditions	Moist
Observation method	Pit
Described by	W.E. Cotching

Great Sandy – Red deep sand profile

A	0-0.5 cm	Red (2.5YR 5/6); sand; loose consistence; single grain structure; sharp smooth boundary.
C	0.5-100^{+} cm	Red (2.5YR 4/8); sand; loose consistence; single grain structure; few fine roots.

Roebuck – Calcareous deep sand summary

Land system inventory point no.	FRA 7
Date	16 February 1990
Station	Frazier Downs
Traverse no.	2
Location on traverse	12.8 km
Grid reference	1:100,000 Map sheet 3260 La Grange
Australian map grid (AMG) co-ordinates	E 374 200, N 7 940 300, Zone 51
Photo no. and date	La Grange run 9/5186, 1988
Land system	Roebuck
Land unit	9
Australian Soil Classification	Shelly Rudosol
WA Soil Group	Calcareous deep sand
Great Soil Group	Calcareous sand
Soil family	Beach dune complex
Principal Profile Form	Uc 1.11
Parent material	Calcareous sand
Geomorphology	Landform - dune position - crest slope - 0^0
Erosion	Nil
Surface condition	Loose
Moisture conditions	Slightly moist to dry
Observation method	Pit
Described by	W.E. Cotching

Roebuck – Calcareous deep sand profile

A	0-27 cm	Brown (10YR 4/3); sand; loose consistence; single grain structure; abundant fine roots; many fine shell fragments; distinct smooth boundary.
C	27-100^+ cm	Yellowish brown (10YR 5/4); sand; loose consistence; single grain structure; few fine roots; few fine shell fragments.

Phire – Shallow gravel summary

Land system inventory point no.	NIT 9
Date	16 February 1990
Station	Nita Downs
Traverse no.	3
Location on traverse	4 km
Grid reference	1:100,000 Map sheet 3259 Cudalgarra
Australian map grid (AMG) co-ordinates	E 380 600, N 7 886 600, Zone 51
Photo no. and date	Munro run 2/5155, 1985
Land system	Phire
Land unit	4
Australian Soil Classification	Sequi-Nodular Tenosol
WA Soil Group	Loamy gravel
Great Soil Group	Lithosols
Soil family	-
Principal Profile Form	KS Uc 5.21
Parent material	Laterite gravels
Geomorphology	Landform - stony plain position - slope - flat
Erosion	Nil
Surface condition	Loose
Moisture conditions	Dry, slightly moist
Observation method	Pit and auger
Described by	W.E. Cotching

Phire – Shallow gravel profile

		Laterite gravels on surface.
A	0-9 cm	Dark reddish brown (5YR 3/4); gravelly loamy sand; moderately strong consistence; massive breaking to single grain structure; many fine roots; indistinct smooth boundary.
B	9-50^{+} cm	Yellowish red (5YR 4/6); medium and coarse (5-20 mm) gravels in a sandy loam matrix; very strong to dig; single grain structure; few fine roots.

Yeeda – Red deep sand summary

Land system inventory point no.	SHA 14
Date	21 December 1989
Station	Shamrock
Traverse no.	4
Location on traverse	33.2 km
Grid reference	1:100,000 Map sheet 3360 Thangoo
Australian map grid (AMG) co-ordinates	E 400 400, N 7 920 700, Zone 51
Photo no. and date	La Grange run 12/5099, 1988
Land system	Yeeda
Land unit	1
Australian Soil Classification	Regolithic Red-Orthic Tenosol
WA Soil Group	Red deep sand
Great Soil Group	Earthy sands
Soil family	Cockatoo
Principal Profile Form	Uc 5.21
Parent material	Aeolian Quaternary sand
Geomorphology	Landform - sandplain position - slope - 1º
Erosion	Nil
Surface condition	Loose
Moisture condition	Dry
Observation method	Pit
Described by	W.E. Cotching

Yeeda – Red deep sand profile

	0-0.3 cm	Red (2.5YR 5/6); coarse sand; loose consistence; single grain structure; sharp smooth boundary.
A11	0.3-0.6 cm	Dark reddish brown (2.5YR 5/4); sandy loam; very weak consistence; weakly developed fine platy structure*; sharp smooth boundary.
A12	0.6-10 cm	Dark reddish brown (2.5YR 3/4); sand; moderately weak consistence; weakly developed subangular blocky breaking to single grain structure*; few fine roots; distinct smooth boundary.
B21	10-27 cm	Dark red (10YR 3/6); sand; moderately firm consistence; moderately developed medium and coarse subangular blocky breaking to single grain structure*; few fine roots; indistinct smooth boundary.
B22	27-52 cm	Red (10R 4/8); medium and coarse sand; moderately firm consistence; weakly developed angular blocky breaking to single grain structure*; few fine roots; diffuse smooth boundary.
C	52-100^{+} cm	Dark red (7.5R 3/8); loamy coarse sand; moderately firm consistence; massive breaking to single grain structure*; very few fine roots.

* It is unusual for this level of structure to occur with sand textures, however, the authors original descriptions have been retained.

Yeeda – Red deep sand summary

Land system inventory point no.	SHA 16
Date	21 December 1989
Station	Shamrock
Traverse no.	5
Location on traverse	5.4 km
Grid reference	1:100,000 Map sheet 3360 Thangoo
Australian map grid (AMG)	E 401 200, N 7 936 400, Zone 51
Photo no. and date	La Grange run 10/5171, 1988
Land system	Yeeda
Land unit	3
Australian Soil Classification	Regolithic Red-Orthic Tenosol
WA Soil Group	Red deep sand
Great Soil Group	Earthy sand
Soil name	Yabbagoddy
Principal Profile Form	Uc 5.21
Parent material	Aeolian Quaternary sand (near laterite outcrop)
Geomorphology	Landform - ridge top position - slope - flat
Erosion	Nil
Surface condition	Loose
Moisture conditions	Dry
Observation method	Pit
Described by	W.E. Cotching

Yeeda – Red deep sand profile

	0-0.3 cm	Red (2.5YR 5/6); coarse sand; loose consistence; single grain structure; sharp smooth boundary.
A11	0.3-0.8 cm	Dark reddish brown (2.5YR 5/4); loamy sand; very weak consistence; weakly developed fine platy structure*; sharp smooth boundary.
A12	0.8-6 cm	Dark reddish brown (2.5YR 2.5/4); sand; moderately weak consistence; weakly developed medium and coarse subangular blocky breaking to single grain structure*; many fine roots; distinct smooth boundary.
B21	6-15 cm	Dark red (10YR 3/6); sand; moderately firm consistence; weakly developed medium subangular blocky breaking to single grain structure*; many fine roots; indistinct smooth boundary.
B22	15-29 cm	Red (10R 4/6); coarse sand; moderately firm consistence; weakly developed angular blocky breaking to single grain structure*; many fine roots; indistinct smooth boundary.
C	29-70^{+} cm	Dark red (7.5R 3/8); coarse sandy loam; moderately firm consistence; massive breaking to single grain structure*; few fine roots.

* It is unusual for this level of structure to occur with sand textures, however the authors original descriptions have been retained.