An inventory and condition survey of the Murchison River catchment and surrounds, Western Australia
An inventory and condition survey of the Murchison River catchment, Western Australia

By: P.J. Curry, A.L. Payne, K.A. Leighton, P. Hennig and D.A. Blood

Editor: K.M.W. Howes
The authors

P.J. Curry, A.L. Payne, P. Hennig and D.A. Blood, Natural Resources Assessment Group, Department of Agriculture, Western Australia and K.A. Leighton, Geodetic Branch, Department of Land Administration, Western Australia.

Other contributors

A. Laws, Geological Survey, Department of Minerals and Energy, Western Australia.

Acknowledgments

This survey could not have been conducted without the cooperation, advice and assistance of pastoralists throughout the area. The authors also wish to thank L.J. and H. Merritt for providing essential logistical support, L.J. Merritt, J.J. Neil and R.J. Cranfield for valuable assistance with the field work, staff of the Western Australian Herbarium (particularly R.J. Cranfield) for identification of plant specimens and numerous colleagues who provided constructive criticism on parts of this report. I. Foster's contribution to the climate chapter is particularly acknowledged. Finally, the authors wish to thank the staff of the Department of Agriculture's Word Processing Centre who typed up and reworked the drafts of our manuscript with patience and precision.

National Library of Australia Cataloguing-in-Publication

An inventory and condition survey of the Murchison River catchment, Western Australia.

Bibliography.
ISBN 0 7309 5998 8.

1. Pastures—Western Australia—Murchison River Region. 2. Rangelands—Western Australia—Murchison River Region. I. Curry, Peter J. II. Western Australia. Dept. of Agriculture. (Series: Technical bulletin (Western Australia. Dept. of Agriculture); no. 84).

633.202099413

1 Current address
PO Box 316
Kelmcott 6111 WA
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>1</td>
</tr>
<tr>
<td><strong>The Murchison River catchment</strong></td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>Brief history of pastoral use</td>
<td>6</td>
</tr>
<tr>
<td>Climate</td>
<td>10</td>
</tr>
<tr>
<td>Geology and hydrogeology (A. Laws)</td>
<td>21</td>
</tr>
<tr>
<td><strong>The Survey</strong></td>
<td></td>
</tr>
<tr>
<td>Methods</td>
<td>38</td>
</tr>
<tr>
<td>Land systems</td>
<td>48</td>
</tr>
<tr>
<td>Landform development and soils</td>
<td>274</td>
</tr>
<tr>
<td>Vegetation</td>
<td>285</td>
</tr>
<tr>
<td>Condition of the land resource</td>
<td>338</td>
</tr>
<tr>
<td><strong>Appendices</strong></td>
<td></td>
</tr>
<tr>
<td>1. Station summaries</td>
<td>353</td>
</tr>
<tr>
<td>2. Vascular plants of the Murchison River catchment area</td>
<td>413</td>
</tr>
<tr>
<td>3. Distribution by land type of common perennial species</td>
<td>426</td>
</tr>
<tr>
<td>4. Inventory site and condition site recording sheets</td>
<td>429</td>
</tr>
<tr>
<td>5. Inventory and condition site data (microfiche)</td>
<td>inside back cover</td>
</tr>
<tr>
<td>6. Land system maps (1:250,000 scale)</td>
<td></td>
</tr>
</tbody>
</table>
Summary

Scope of the survey

The area surveyed by fieldwork during 1985-88 covers approximately 88,360 km² of arid zone rangelands situated between Mt Magnet and Meekatharra in the east and the catchments of the Greenough and Wooramel rivers in the west. This area includes most of the catchment of the Murchison River and its tributaries the Sanford, Roderick and Yalgar rivers; as well as most of the catchment of Lake Austin.

Land use in the area is dominated by 67 pastoral leases, the lands of which fall wholly within the survey in 53 cases and partly so for 14 others. Gold mining was the only other land use operating at a high level of activity, throughout the auriferous areas.

This report details a descriptive reference accompanying a 1:250,000 scale map series to the biophysical characteristics of the area. Descriptions of climatic patterns, geology and hydrogeology, soil types, land types, land systems, land units and vegetation types are presented as a regional inventory of land resources.

Land characteristics

The survey area exhibits a characteristically arid climate (mean annual rainfall 190-240 mm) throughout, with the exception of the moister far south-western corner. When subjected to analysis in terms of moisture potential for widespread plant growth, long-term records show the clear predominance of effective winter rainfall (probability 55-80% throughout) and the highly unreliable nature of effective summer rainfall (< 20% throughout). A probability-based assessment of rainfall and plant growth presented here provides a basis for long-term strategic planning for pastoralists and other land managers who are operating in a highly erratic and unreliable seasonal environment.

Geologically, the area is dominated by a granite-greenstone terrain of the Archaean Yilgarn Craton, with the hill ranges widely separated by very flat plains derived from colluvium and alluvium. Soils are mainly shallow, sandy and infertile, and across most of the lower areas are distinctively underlain by red-brown siliceous hardpan.

Shallow aquifers found extensively below this hardpan and elsewhere have provided most of the groundwaters on which development of the area for pastoral and mining industries has depended. Groundwater consumption by the pastoral industry is small compared to estimated storage. The origins and quality of groundwater was described from survey work conducted by the Geological Survey (Department of Minerals and Energy) in the context of 12 major sub-catchments in the area.

Lands within the area have been described and mapped into 19 broad land types composed of 74 land systems. Their individual extent varies greatly, and over half the area is made up by just eight land systems (Yanganoo, Kalli, Koornarra, Challenge, Sherwood, Belele, Mindura and Narryer). The land system approach attempts an integrated or natural classification of land from predominant biophysical features in an inventory which will be useful to all future land management and land use planning.

At a more detailed level, the component land units of each land system are described by their landform features, soils and vegetation associations. In this way, the mapped divisions of the landscape are related through their component parts to any position or site of interest on the ground.

Vegetation

The flora of the area is diverse, with about 830 recorded vascular species, of which 97% are native and about 4.5% endemic or near-endemic. No described species are thought to have become extinct. Associations considered at the scale of the land unit are objectively classified and described as 23 major types. All but three of these types are shrublands or low woodlands of which the majority are naturally depauperate in grasses. Mulga (Acacia aneura) and cotton bush (Ptilotus obovatus) are the most ubiquitous perennials.

Intensive sampling of 14 of these types at 1256 'condition sites' throughout the area revealed the patterns of variation that exist, partly as natural variation but otherwise as a consequence of changes related to cumulative impact by grazing animals and pastoral management. In this way, analysis of the observed variation in perennial vegetation at comparable sites has enabled simple and objective criteria to be defined for classes of vegetation condition. Land managers and administrators will be able to reassess the condition of vegetation in an area of interest and compare their findings with quantified relativities recorded during 1985-88.

In terms of adverse impact on perennial communities by pastoral usage, approximately 42% by area of all vegetation was in poor to very poor condition, 37% remained in fair condition and 21% was still in good to very good condition. Taken overall, these summary data indicate that the vegetation in this survey area is in poorer condition than that recorded from other regional rangeland surveys in Western Australia.

General symptoms of poor condition are a loss of perennial plant diversity and numbers per unit area, loss of palatable perennial diversity and density, while sites in the poorest condition states show general loss of vegetation structure, cover and hence subsequent denudation. Secondary increases and invasions by unpalatable species such as prickly acacia (Acacia victoriae) and needle bush (Hakea preissii) are common on disturbed or deflated soil surfaces, mainly on river
and tributary alluvial plains with duplex soils. The most widely degraded vegetation types are the halophytic shrublands (mainly saltbush and bluebush types), hardpan mulga shrublands and calcrete shrubby grasslands. They have been preferentially grazed for 80-110 years in most areas.

Introduced (exotic) plants in the area are mainly local in occurrence, annual or short-lived species, and associated with disturbed or nutrient-enriched or wetland sites.

Soils and soil erosion

Accelerated soil erosion is widespread in the area. Arested areas invariably show perennial vegetation in less than good condition. Erosion problems have evidently started and accelerated primarily as a consequence of loss of perennial vegetation. Natural processes which serve to stabilise otherwise vulnerable soil surfaces have been fragmented or disrupted. Many land units and soil surfaces on stony hills and plains are highly resistant to erosion. Others are highly susceptible. The pivotal role of perennial vegetation in good condition on susceptible soils is illustrated by the major vegetation type, hardpan mulga shrubland, in which sites exhibiting either of the two most diverse and dense vegetation condition classes were never encountered showing significant accelerated erosion. Sites in the more depauperate vegetation classes showed a 9% incidence of accelerated erosion.

By two different survey methods the incidence of at least minor accelerated erosion was estimated at 15-17% of the area. Commonest forms of erosion are scalding and surface sheeting over 10-50% of the surface. The most susceptible soil types are red duplex types on areas with some slope and subject to concentrated sheet flows after major rainfall events.

The preponderance of shallow soils (< 50 cm deep over hardpan or baserock) has meant that this erosion is not characterised by spectacular gullying. Nor has the problem been highlighted by acute off-site effects, such as siltation of dams or estuaries. Eroded areas in the Murchison are mainly patchily vegetated or denuded flats, with deflated or no topsoil and exposed saline subsoils or inert hardpan remaining as the land surface.

Areas of extensive severe degradation and erosion (sde) larger than 40 ha were mapped and total 1.8% of the survey area (1561 km²), an area more than half as large as the Australian Capital Territory. The incidence of sde is largely confined to a small number of susceptible and preferentially grazed land units, mainly on Beringarra, Ero and Sherwood land systems.

Historical cf. contemporary effects

The Murchison's history and its development as a major pastoral and mining area indicates a high correlation between the location of early pastoral development along the river plains with the present-day patterns of pastoral use and the recorded incidence of land degradation. Parts of many individual leases showed clear signs of recent recovery in the perennial vegetation. However, some local areas of recent vegetation degradation and soil erosion were encountered.

Management implications

For the present pastoral industry, about half of the land area grazed is in mainly poor condition but not severely degraded and eroded. It is these areas with mainly intact soil surfaces which present the best prospects for economically feasible perennial regeneration in the short to medium term.

Most of the eroded duplex plains will remain irreversibly deflated and degraded until practical solutions are more fully researched and developed (a) to manage total grazing pressure throughout each affected sub-catchment; and (b) to enhance plant establishment and soil accretion on deflated areas on the major drainage systems and breakaway footslopes.

Aerial census of kangaroos, goats and other large animals, conducted across the area at the time of the survey indicated that the grazing pressure exerted by domestic stock was less than 50% of the total pressure from all grazing animals. Successful control of kangaroos and goats will be essential for implementing vegetation regeneration by controlling all grazing pressure.

The operating circumstances and financial position of woolgrowers in the area has changed rapidly for the worse since the survey began and will probably continue to change. Environmental awareness and technical knowledge of the soil and vegetation patterns within the pastoral industry and the wider community continues to grow. In terms of management recommendations, this report marks a significant departure from previous surveys, in which broad recommendations were made about how pastoralists might change management practices to address land degradation problems. The failure of such a government-led approach to the problem of land degradation and management planning in rangelands (and any other land under productive use) is now widely acknowledged.

It is therefore most appropriate that this report provides an enduring technical reference to assist Land Conservation District Committees (which became established throughout the area during the survey program) and other stakeholders to become more deeply engaged in management planning, monitoring and technical investigations. In addition the report stands as a reference work useful to various Government agencies and private enterprises concerned with land use and land use planning in the region.
The Murchison River Catchment

Introduction

Rangeland surveys

The findings presented in this report are those of a regional survey of rangelands in the Murchison River catchment area of Western Australia. The work was undertaken by a joint team from the Department of Agriculture and the Department of Land Administration during 1985-88. This survey is the seventh of its type, in a program of land classification, mapping and natural resource evaluation in pastoral areas of the State. Other surveys in the program have been undertaken in the Gascoyne River catchment (Wilcox and McKinnon 1972), the West Kimberley (Payne et al. 1979), part of the Nullarbor Plain (Mitchell et al. 1979), part of the Ashburton River catchment (Payne et al. 1982), the Carnarvon Basin (Payne et al. 1987) and the Roebourne Plains (Payne and Tille 1992). Field work on an eighth survey in the north-eastern Goldfields region was completed in 1990 (Pringle et al. 1994).

Murchison River catchment

The survey covered about 88,360 km² of land which is mostly under pastoral leaseholding, within the Murchisonia physiographic sub-division of Jutson (1950) and the Austin Botanical District of the Eremaean Botanical Province (Beard 1980). The area encompasses most of the catchment of the Murchison River and its tributaries the Sanford, Roderick and Yalgar rivers and also the headwaters of the Wooramel and Greenough rivers.

The survey area extends from Innouendy and Mt Gould stations in the north to Bullardoo and Wondinong stations in the south and to Polelle and Muggon stations in the east and west (Figure 1). Three small towns, Meekatharra, Cue and Mt Magnet, are situated in the east and south-east with the tiny settlement of Murchison in the west. A prominent feature in the south-east of the survey area is the extensive salt lake, Lake Austin. Smaller salt lakes include Lake Anreen between Cue and Meekatharra and the lakes on Muggon station in the far west. In the north, the boundaries of the survey were fixed at the limits of coverage achieved by the Gascoyne River catchment survey (Wilcox and McKinnon 1972) and in the north-west by the boundary of the Carnarvon Basin survey (Payne et al. 1987). In the east, the survey area overlapped with part of the Wiluna-Meekatharra survey (Mabbutt et al. 1963). Elsewhere the boundaries of the survey area were more or less defined by the boundaries of the 1:250,000 map sheets shown in Figure 2.
The survey area includes nearly all of the Murchison and Cue Land Conservation Districts (LCDs) and parts of the Yalgoo, Mt Magnet and Meekatharra LCDs.

The report

The purpose of the survey was to provide a comprehensive description and mapping of the biophysical resources of the region, together with an evaluation of the pastoral potential and the condition of the soils and vegetation. The report and the accompanying series of colour maps at 1:250,000 scale are primarily intended as a reference for present and future land managers, rangeland advisers, other state and local government officers and land administrators, the people most involved in planning and implementing management practices. The report and maps will also provide researchers and the public with a basic reference on the biogeographic features of the Murchison River catchment. The survey inventory also enables the recognition and location of land types of particular potential, land use or conservation value.

Survey findings give new perspectives on each type of land in good and poor condition, and the special circumstances of severely degraded areas. These can be considered by individual lessees and managers, Land Conservation District groups and by all future programs of government assistance to land managers. The report presents essential resource information required to plan sustainable land management at the scales of sub-catchment, lease or paddock.

This report provides vegetation type descriptions and indicates the spatial relationships of land units necessary for the strategic location of monitoring sites. It also provides information for ‘do it yourself’ assessment of condition of major vegetation types, and objective criteria by which such future assessment can be compared to this baseline survey. Monitoring of vegetation change is well established in the Western Australian rangelands, and can be considerably enhanced by such insight.

The first three sections of this report provide an overview of historical aspects of land use and the fundamental biophysical features of the survey region. In many instances, little detailed information has been previously published for the region. These sections draw together some of the disparate information which is available and serve as an introduction to the later, more detailed land system descriptions and the detailed accounts of vegetation and soils. The Geology and Hydrogeology section includes a description of the physiography of the region which relates directly to the land systems (or more precisely to groups of land systems) which are detailed later in the report.

The three major sections within the report are the land system descriptions, vegetation types and soils. These sections provide information on landform, vegetation and soil at mapping scale and within map units at the land unit level. Used in conjunction with the maps, these provide an inventory of the whole rangeland resource.

The Appendices provide information too detailed to include within the text of the main report. Included are listed summaries of biophysical data collected at 1,968 individual sites investigated during the survey. These original data have been made available for the reference of individual lessees and managers, who may wish to use such sites as benchmarks.

Changing face of the pastoral industry

The period over which the survey was conducted and its results subsequently analysed has been marked by rapid and serious changes of circumstance for the pastoral industry of the region. In 1985, the economic setting was one of high wool prices and a buoyant Australian economy. Following the Australian Stock Market crash in 1987, wool prices fell, to be followed by the removal of the floor price support scheme in 1990. A decline in premiums for fine wools and record low prices have continued throughout 1992 and 1993.

Such severe economic pressure on the industry has brought previously profitable properties to crisis point. Complementary income derived from other industries and enterprises on pastoral leases, mainly from mining and tourism, and the relatively favourable position for cattle producers, have been critical in the continued operation of some leases. The full extent of the consequences for the future structure and operation of individual leases and the industry as a whole, is still unclear.

A regional inventory such as this will be of value in planning and managing the changing patterns of pastoral land use, as well as for investigating the potential of new and developing industries based on natural resource management.

References


Aerial view of a typical area of 'river frontage' country. The large central portion depicts an alluvial plain on which the gross signs of accelerated water erosion are predominant. Note the lack of seasonal vegetation growth on the affected surfaces. The major river channels, flanked by coolabahs and river red gums, are visible in the top right.


Brief history of pastoral use

The Murchison River was named after Roderick Impey Murchison, President of the Geographic Society, London, by Lt George Grey in 1839.

Assistant surveyor Robert Austin led the first expedition through the upper Murchison, travelling west from the southern fringes of Lake Austin during the spring of 1854. After a dry or indifferent winter season, Austin’s party was repeatedly short of water and almost perished towards the end of the journey. As a consequence, Austin did not assess the Murchison as having pastoral potential. The first claims of promise for grazing potential were made by F.T. Gregory, S. Trigg and J. Roe in 1857, who reported grass ‘two to three feet high’ around Mt Welcome, and ‘a fine sward of grass’ below the gums on the river. They concluded that the area was ‘fair average cattle pasture’.

The first sheep to be grazed along the upper Murchison River were brought through the area by E.T. Hooley, who successfully drove a flock from Galena to the Ashburton in the winter of 1866. By this time T. Burges and J. Perks were already bringing flocks along the Greenough River as far as Yuin, and were granted the first pastoral leases made available in the region, in 1864, as 10,000 acre blocks leased for fourteen years. Burges and the Wittenoom brothers led the first wave of pastoral settlement and development which proceeded up the main arms of the Murchison River during the late 1860s and 1870s.

Early selections of country

Pioneer pastoralists made their first choices of country for pastoral leases along the river plains of the Greenough, Sanford, Murchison and Roderick rivers. Small blocks which are now parts of Yuin, Murgoo, Boolardy, Wooleen, Woolgorong, Wandina

Figure 3. Pastoral leases on the Murchison River and its tributaries as at about 1880.
and Byro stations were settled by 1874. F. Wittenoom continued to explore the upper Murchison River, and by 1880 Nookawara, Billabalong, Beringarra, Milly Milly, the present Boolardy (Wittenoom's headquarters), Murgoo and Annean were established (Figure 3).

Sites selected for early shepherds' camps, and subsequently for homesteads, generally had two common features: one or more wells yielding plentiful water of an acceptable quality and proximity to the river plains. Most homesteads became established near some point where hardpan wash plains meet headwaters, and on a slightly elevated site (such as a calcrete platform) which was more or less flood free. Wells sunk in the alluvium further out on the river plains proved brackish or saline more often than not. Thus, the first land used for pastoral development tended to be the zones around the wells, of which the shallowest (to dig by hand into 'Murchison cement' or red-brown siliceous hardpan) and most reliable were sought after. Such strategic locations for the wells allowed grazing access to both the mulga country of the sheet wash (or ‘wanderrie’) plains and the more saline river plains with their extensive bluebush and saltbush and more local perennial grass pastures on the clayey drainage zones and the limestone platforms. Away from the river frontages, New Forest station appears to have been established on the strength of its reputation as a water supply alone.

In this initial phase of settlement, higher country away from the rivers was virtually ignored. Flocks were shepherded and little or no infrastructure was used other than brush yards for confining animals at night and for shearing. It was not until the first decade of the twentieth century that wire fences and windmills were erected for stock control around the established pastoral settlements.

Early compilations of the boundaries of pastoral leases shown on Lands Department plans suggest that there was some contraction in the extent of areas leased after the initial major wave of occupation before about 1895. Areas of granite country with kite leaf poison, and the waterless ‘bowgada’ sandy plains, were two types of country subsequently avoided by pastoral developers. However, pastoral settlement continued and was enhanced in the 1890s when gold was discovered in the Murchison and new towns and a railway link to the coast were built. By 1900 the areas held under lease had expanded greatly (although some were not occupied or developed) and incorporated all of the frontage lands to the Murchison River and its tributaries and much of the hinterland (Figure 4).

In 1890, the Wittenoom brothers are said to have sold Murgoo Station to Messrs Holmes and Maloney with 16,000 sheep. Flock sizes were generally built up rapidly, under expectations of huge carrying capacities. A description of the new shearing shed at Milly Milly in 1887, describes it as ‘capable of providing accommodation for 100,000 sheep’ (The West Australian, 16 November 1887).

The enormous seasonal variations in grazing productivity inherent in the Murchison's arid environment were well understood by some pioneer pastoralists in the light of their shepherding experience accumulated before 1900. Frank Wittenoom commented in his journal that:

'The Murchison country is so light carrying that runs were very large. It would be hard to strike the average carrying capacity as in a really good season it would carry a sheep to 2 or 3 acres, but in a bad season, 100 acres or more. The top feed is wonderful in a drought'.

Arguably, it was the recurrent predicament of seasonal failure and the needs of the early industry to maintain stock, on the same country and in the absence of alternative pastures or marketing opportunities, that initiated the degradation of vegetation and soils on the frontage plains.

River frontage plains with productive soils and vegetation attracted the early pastoralists into the Murchison; sago bush-dominated plain of the Beringarra land system, Mileura station.

Development after 1900

Between 1900 and 1930 there was a rapid expansion and development of leases. Shepherding declined as stations became more developed with paddocks and water points away from river frontage country. Wool prices were generally good. By 1918 sheep numbers in the present survey area had reached just over 800,000 and later, in 1934, peaked at about 840,000 (Figure 5).

In company with other pastoral areas south of Kimberley, the Murchison suffered a severe drought in the mid and late 1930s. This, coupled with very high initial sheep numbers, resulted in large sheep losses and extensive damage to vegetation. Burnside (1979), using information from Fyfe (1940), states that sheep numbers in pastoral areas of Western Australia fell from 5,519,000 to 3,051,000 between 1934 and 1939. In the area covered by the present survey, sheep losses were even more drastic with numbers falling from 840,000 in 1934 to about 250,000 in 1940 (Figure 5). In the Murchison-Meekatharra area, it was estimated that by 1940, 75 per cent of the saltbush (Atriplex spp.) and 25 per cent of the acacias had been destroyed. Losses of up to 90 per cent of scrub and shrubs were reported.
Seasons during the 1950s were mediocre but better seasonal conditions in the 1960s saw partial recovery of pastures and modest recovery in sheep numbers from the drought induced low of 1940. High wool prices compensated for reduced stock numbers and pastoralists generally enjoyed a prosperous period.

In recent decades poor wool prices and the natural vagaries of climate have again posed severe difficulties for the pastoral industry. In the survey area sheep numbers fell to an all time low of about 250,000 in 1980 but by 1990 had recovered to 430,000. Figure 6 shows the location and extent of present day pastoral leases in the survey area. The total area held under lease is similar to that of 1900 but amalgamation and restructuring has resulted in fewer, generally larger, leases in 1990.
In the early days of settlement most people involved with the industry, including explorers, surveyors, pastoralists and land administrators had unrealistic expectations as to the productive capacity of the land. In an environment where there was no information on the effects of continuous grazing on native vegetation and soils the land was grazed at levels which were non-sustainable.

The Murchison pastoral lands remain a valuable renewable resource but many formerly favoured parts are historically degraded and the vegetation and soils are still under heavy pressure from domestic, feral and native animals.

The challenge for today’s managers is to run a viable livestock enterprise whilst at the same time ensuring that each country type is used according to its capability for sustained production. An additional aim for managers needs to be the rehabilitation of degraded areas.

References and further reading


Fyfe, W.V. (1940). Report of Royal Commission appointed to enquire into and report upon the financial and economic position of the pastoral industry in the leasehold areas in Western Australia. Govt. Printer, Perth.


Climate

Introduction

The climate of the Murchison River catchment is described by Meigs (1953) and most subsequent authorities as being arid. Beard (1976) followed Bagnouls and Gaussen (1957) classifying the area as ‘desert’ with bimodal (summer and winter) rainfall trending to semi-desert Mediterranean in the southwest corner.

Climatic descriptions generally classify an area as arid when it normally receives insufficient rainfall to sustain the growth of rainfed crops at any season. Because of regional variations in latitude, seasonal patterns of rainfall and evaporation deficits, aridity cannot be universally defined by the mean annual rainfall being below a certain figure. As a working delineation for the southern boundary of the arid zone of Western Australia, several authors have stressed the coincidence between the 250 mm isohyet for mean annual rainfall and the transition between the Eremaean (arid) Botanical Province and the South-Western Botanical Province (Beard 1976, Curry and Hacker 1990).

The mean (average) annual rainfall for the region is about 210 mm, ranging from about 240 mm in the southwest to about 190 mm in the north-east.

The dominant synoptic feature of the region’s climate is the subtropical high pressure cell, which is composed of descending air and brings fine and stable weather conditions and prevailing easterly winds when located to the south of the survey area. The high, with its associated ridge is at its northernmost during winter and is most southerly during summer, gives rise to two dominant seasons. This is accompanied by large variations of temperature and moisture availability.

Sources of climatic data

Long-term climatic information for representative recording stations in, or adjacent to, the survey area, was obtained from the Bureau of Meteorology. Eight of the stations (Cue, Mt Magnet, Meekatharra, Billabong, Meeberrie, Byro, Milleura and Murgoo) are within the survey area and two stations (Errabiddy and Yalgoo) approximate to northern and southern limits of the area (see Figure 7). Together, the records from all these centres give a cross-section of essential climatic conditions throughout the region.

Seasonal patterns

1. Summer (November to April)

Summers are characterised by hot, dry days and mild to warm dewless nights. The summer synoptic weather pattern is dominated by a high pressure anticyclonic cell located south of Western Australia, which brings fine and warm conditions to the Murchison. As the anticyclones move eastward, a trough often develops along the west coast of Western Australia bringing dry north-easterly winds from central Australia (see Figure 8). Occasionally a low pressure cell is formed in the trough causing day-time temperatures east of the trough to rise sharply. After a few days the trough moves eastward and is followed by cooler north-west to south-west winds which bring a cool change across the region. The cycle of steady warming begins again as a new anticyclone moves into the Great Australian Bight. Average maximum daily temperatures range from 38°C in January, to 29°C in April. Maxima exceed 42°C at least once a year everywhere in the area. The average daily minimum temperatures range from 22°C to about 14°C (Figure 9).

An occasional influence is the development of intense low pressure disturbances off the north-west coast of Western Australia. These depressions can form tropical cyclones which often intensify near the Pilbara coast. Some cyclones run parallel to the coast, while others dissipate out to sea. Cyclones that cross the coast weaken as they move inland and become rain bearing depressions. Cyclones can occur at any time between November and April but their frequency is highest in the late summer months February and March. The intensity of rain varies from light drizzle to widespread heavy falls.

While minor localised flooding is not uncommon, major floods are few. Historical descriptions and climatic records suggest there have been about nine major floods since 1848. Before 1960 the severity of floods was not recorded but since then major flooding has occurred in 1960, 1975 and 1980.
Thunderstorms resulting from convectional activity bring sharply isolated falls of highly variable intensity throughout the region. Cyclones and thunderstorms thus provide the summer rainfall which occurs in two contrasting ways, either as rare widespread major falls or common localised minor falls which may be very heavy over a small area. The average monthly rainfall varies from about 5 mm in November to about 26 mm in January and February (Figure 9), with very low reliability in any particular month (Figure 10).

Rainfall during March-April, when significant, is likewise invariably derived from incursions of tropical air and is accompanied by relatively high temperatures. For these reasons, the growth response is of the summer type rather than that derived from rainfall received from May and later during winter.

2. Winter-Spring (May to October)

Winter is characterised by mild days and cool to cold nights. The beginning of winter is often marked by increased cold frontal activity associated with low pressure cells located well to the south of Western Australia in the Southern Ocean. Rain bearing cold fronts cross the south west coast of Western Australia and usually weaken considerably before reaching the Murchison region. Only strong fronts penetrate far enough inland to bring isolated showers and occasional strong winds (see Figure 11).

Occasionally cloud bands originating from the tropics to the north-west of the State interact with fronts to provide rain over central parts of Western Australia including the survey area. The frequency of such cloud bands is highest in the months of May, June and July, while the frequency and intensity of cold fronts peak in June and July.

The average monthly rainfall for May and June is between 25 and 40 mm and is the most reliable rainfall received throughout the region. Even so, the monthly coefficients of variation only decline to about 100%, reflecting the experience that anything between zero
Figure 9. Mean monthly temperatures and rainfall at six centres.
Figure 10. Annual variation in mean monthly rainfall expressed as percentage coefficient of variation.

Frosts occur occasionally in the mid-winter months throughout the area (Table 1). In the east, the average number of frosts during July and August is one to two, while in the central west and west the average is two to four. While the average number of frost days is low it may vary considerably between years. Mt Magnet recorded 11 frost days in July 1957, yet in 1959 in the same month no frosts were recorded.

Table 1. Frosts in Murchison region

<table>
<thead>
<tr>
<th>Station</th>
<th>Frost days (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>June</td>
</tr>
<tr>
<td>Errabiddy</td>
<td>0</td>
</tr>
<tr>
<td>Meekatharra</td>
<td>0</td>
</tr>
<tr>
<td>Cue</td>
<td>0</td>
</tr>
<tr>
<td>Mt Magnet</td>
<td>1</td>
</tr>
<tr>
<td>Murgoo</td>
<td>0</td>
</tr>
<tr>
<td>Yalgoo</td>
<td>1</td>
</tr>
</tbody>
</table>

Rainfall and rainfall effectiveness for plant growth

Trends across the area

The annual average rainfall for the survey area is generally lowest in the north-east and higher in the west and south. The highest mean monthly rainfall is in June throughout the region except in the north-east where the highest monthly mean rainfall is in January.

Figure 11. Surface chart depicting a typical winter synoptic pattern. The winter pattern depicts the passage of a cold front with its northern parts about to cross the survey area while an anticyclone has moved eastwards to be centred on Victoria.
This difference in the peak of seasonal rainfall distribution reflects a steady geographical trend across the survey area. In the extreme south-west, winter rainfall is sufficient and regular enough to support semi-arid South Western Botanical Province vegetation, which dominates the Irwin Botanical District further west. A trend of decreasing winter rainfall and increasing summer rainfall exists from the south-west to the north-east. Winter rainfall accounts for about 46% of Errabiddy’s yearly total, while at Yalgoo and Murgoo the figure is about 61%. Similarly on the eastern margin of the region less winter rain is recorded in the north than the south. At Meekatharra a mean of 46% of the annual rainfall is recorded during winter while at Cue the figure is 50% and at Mt Magnet, 52% (Figure 12).

The reliability and effectiveness of rainfall is the most critical factor in determining plant growth. The variability of rainfall expressed as coefficient of variations (Figure 11) shows rainfall is most reliable (but still highly variable) everywhere from May to July when rainfall is likely to be at its highest and least reliable from September to December when rainfall is at its lowest. Mid to late summer (January to March) shows less extreme monthly variation than early summer owing to a low peak of some rainfall expectancy from cyclones and thunderstorms, particularly at Meekatharra more than at other centres further south.

Seasonal patterns of effectiveness

Long-term rainfall trends and annual variation since the early part of this century are shown in Figures 13-15 for Meekatharra, Mt Magnet and Meeberee. The bars represent annual rainfall and the line is a seven year moving average.

Figure 12. Proportions (%) of average winter (May-October) rainfall (shaded) to average summer (November-April) rainfall.

Figure 13. Meekatharra rainfall 1913 to 1991.
Figure 14. Mt Magnet rainfall 1895 to 1991.

Figure 15. Meeberrie rainfall 1909 to 1987.
Several features are apparent from these long-term annual rainfall totals. Firstly, there has been no significant overall trend in rainfall during the century. The apparent decline in Murchison rainfall since the early 1970s is reflected by a similar general decline over south-western Western Australia. There is also little convincing evidence of regular cycles of annual rainfall, although some well-marked cycles, in the incidence of total annual rainfall have occurred over the years.

The most significant feature is the large inter-annual variation of rainfall. Years of well above average rainfall are often followed by very dry years. The coefficient of variation of annual rainfall for these stations ranges from 44% at Meeberrie to 45% at Mt Magnet and Meekatharra, which implies that annual rainfall at Meeberrie will total a figure within 44% of the long-term average in only 68% of years.

Rainfall and the subsequent availability of soil moisture is the dominating environmental factor determining and limiting plant growth in arid Australia. Arnold (1963) and Wilcox (1972) were among the first to emphasise that rainfall effectiveness arising from combinations of discrete falls, rather than average or total annual rainfall, is the key consideration in determining plant growth and other major ecosystem responses, and the productive basis of a grazing industry dependent on the ecosystem.

To estimate frequency and duration of periods of growth from rainfall records and other known meteorological data, a computer model for predicting soil moisture availability was developed for arid to semi-arid mulga country by Fitzpatrick et al. (1967). The model (ARWATBAL) was developed from field observations of soil moisture storage and requires daily rainfall data as its only input variable once the other parameters are set for a particular location. ARWATBAL compares the incoming rainfall against a proportion of the rate of potential evaporation likely at the particular time of the year taking into account some initial water loss from run-off. The balance of moisture stored in the soil is potentially available for plant maintenance and growth.

A growth period in the region is defined as 30 days or more of continuous soil moisture availability, initially requiring over 15 mm of rainfall. Table 2 shows the average length of growth periods and their standard deviations along with the average starting date of a season.

Rainfall sufficient to stimulate significant plant growth falls most frequently in early winter. Perennial shrubs and trees grow new foliage relatively quickly after the event, with ephemeral forbs and 'wildflowers' requiring time to germinate, establish and grow; perennial grasses are inhibited by low temperatures and respond later as temperatures rise.

It is evident from Table 2 that winter is the major growing season throughout the area. This is because lower evaporation during winter permits rainfall to promote plant growth for longer than during summer.

Payne et al. (1975) suggests that because growth rates are higher under the warm to hot summer temperatures, a period greater than only 20 consecutive days of available soil moisture constitutes a significant summer growing season.

The length of winter growth periods as estimated by the model is shown in Figures 16-18 for Meekatharra, Mt Magnet and Meeberrie. In common with annual rainfall plotted in Figures 13-15 there is no evidence of regular cycles of seasonal length, nor of a significant trend during the century. Inter-annual variability is high, with coefficients of variation ranging from 47% at Meeberrie to 69% at Meekatharra. This follows the geographical trend described earlier of more erratic winter rainfall, which is also less variable in occurrence, in the south-west, to a higher proportion of more erratic summer rain in the north-east.

Also apparent is the episodic nature of seasonal growth. This is especially apparent at Meeberrie where a sequence of dry years in the 1930s contrasts with above average years during the late 1940s and early 1960s. Similar events are discernible, though less pronounced, at Mt Magnet and Meekatharra, with the

<table>
<thead>
<tr>
<th>Station</th>
<th>Winter season</th>
<th>Summer season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td>Average length</td>
</tr>
<tr>
<td>Byro</td>
<td>June 5 ± 26 days</td>
<td>51 ± 27 days</td>
</tr>
<tr>
<td>Mileura</td>
<td>June 7 ± 33 days</td>
<td>43 ± 28 days</td>
</tr>
<tr>
<td>Billabalong</td>
<td>May 28 ± 30 days</td>
<td>69 ± 32 days</td>
</tr>
<tr>
<td>Mt Magnet</td>
<td>May 33 ± 26 days</td>
<td>62 ± 32 days</td>
</tr>
<tr>
<td>Meekatharra</td>
<td>May 28 ± 33 days</td>
<td>39 ± 27 days</td>
</tr>
</tbody>
</table>

Table 2. Average starting dates and length of growth periods predicted by ARWATBAL analysis of long-term records.
Figure 16. Meekatharra winter season growth periods 1913-1991.

Figure 17. Mt Magnet winter season growth periods 1913-1991.
addition of a string of above average years in the early 1980s. The recurrent nature of one or more very dry years has been a feature throughout the century.

Long-term seasonal expectations of soil moisture can be summarised in terms of probabilities (Figure 19). The usefulness of this approach is shown by Figure 20 where the predicted number of days of continuous winter growth is plotted against its probability at Meekatharra, Mt Magnet and Meeberrie. Figure 21 shows the predicted number of days of continuous summer growth plotted against its probability at the same three centres.
For all three centres, the chances of having growth rise steeply during May, coinciding with the onset of winter rains, and fall rapidly during September as frontal activity declines. There is little likelihood of spring or early summer rains. The occurrence of effective summer rain increases during late summer (autumn) but remains at less than a 20% chance. Billabalong experiences even less effective summer rain.

At Meekatharra there is a 50% chance of having a winter season of more than 35 days, while at Mt Magnet 50% of years will have a winter season of more than 55 days. It can be seen as a further example that there is a 55% chance of having an effective winter season (more than 30 days) at Meekatharra (and therefore a 45% chance of having a failed season). In contrast, Mt Magnet has an 80% chance of having an effective winter season and a 20% chance (one year in five) of having a seasonal failure.

These probabilities are summarised for winter and summer seasons in Table 3.

### Management implications for pastoralists

Table 3 has critical implications for pastoral land managers who have to make appropriate decisions with regard to both animal husbandry and land management. For example, because the highest nutritional requirements of grazing animals occurs during late pregnancy and lactation, to achieve maximum lambing percentages the lamb drop should coincide with the time of the year in which new growth is most likely to be available. In the Murchison that time would be during the month of July. This is vital, particularly where the perennial forage available to the animals is not in good condition. If no significant rain has fallen by late July it is highly unlikely to occur (less than 5% probability) during that winter. August and September will require decisions on selling excess stock, and where to retain stock over the next summer on existing forage reserves, whenever a failure of the expected winter season has occurred.

On the other hand, general pasture growth from summer rainfall can be considered an unusual bonus rather than something to rely on in a grazing management strategy appropriate to anywhere in the survey. In the majority of years, short-lived periods of soil moisture available during summer will stimulate foliage growth of perennial shrubs and grasses to some degree, plus some germination of seedlings, but the total effect is much less than that of a general growth period.

Foley (1957) summarised droughts in Australia from the earliest years of settlement to 1955. Comparing annual rainfall to yearly averages, assessments were made of dry times, although early pioneers initial understanding of arid zone conditions may have been limited and therefore assessments of early droughts should be treated with caution. However, with settlement, more extensive records were maintained and drought years for the Murchison region where the most significant in 1935-41, 1943-45, 1979-80, with extended dry spells occurring around 1967 and 1982.

Dry times are relatively common in the area, so land managers need to be aware of the statistics of their incidence and be prepared to plan and practice station management according to prevailing seasons and probabilities. Retaining high stock numbers during dry times has often led to a decline in the resource base affecting future productivity. However, management decisions such as selling off and culling to maintain a high quality nucleus flock structure will maintain or improve animal productivity and preserve the productivity of the rangelands.

### References


### Table 3. Growing season probabilities, Murchison region

<table>
<thead>
<tr>
<th>Probability (%) of exceeding growing seasons of durations indicated</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billabalong</td>
<td>Mt Magnet</td>
<td>Meekatharra</td>
</tr>
<tr>
<td>Growing season duration (in days)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>90</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>70</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>40</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>


